NASA

Artemis

Final Presentation
Results of the Engineering Feasibility Study

NASA Johnson Space Center

September 17, 1991

Common Lunar Lander

Engineering Study Results

17-Sep-91

2:00 - 4:00 pm

Time	Speaker	Topic
2:00 - 2:10	Bob Ried	Introduction
2:10 - 2:30	Steve Bailey	Project Perspective
2:30 - 2:50	Jonette Stecklein	Systems Engineering
2:50 - 2:55	Lynn Wagner	Trajectory
2:55 - 3:00	Ed Robertson	Launch Vehicles
5 min	Shelby Lawson	Configuration Design
5 min	George Sanger	Structures
5 min	Don Hyatt	Propulsion
5 min	Nancy Smith	GN&C
5 min	Bill Culpepper	Tracking
5 min	Henry Chen	Communications
5 min	Betsy Kluksdahl	Power
5 min	Diane McLaughlin	Reliability
3:40 - 4:00	Jonette Stecklein	Synopsis - Engr. Product

Building 1, Room 945

N92-18828 #

N92-18841 #

Artemis

A Common Lunar Lander for the Space Exploration Initiative

Presentation to Aaron Cohen

September 17, 1991

Stephen Bailey/IE3/283-5411

Summary of Past & Future Events

Artemis

June 13	• Initial Common Lunar Lander Presentation, Authorization to proceed with In-house study
July 1	• Workshop held at JSC
July 17	• Kickoff meeting of EA spacecraft design study team
August 23	• EA Senior Board Review
Sept 17	• Design team results presentation, distribution to payload developers, sponsors and industry
Oct 11	• External concept assessment complete
Oct 21	• Presentation of program strategy and recommendations Procurement, Management structure, cost estimates, etc.

Stephen Bailey/IE3/283-5411

Artemis Program Rationale

Artemis

- Correctly anticipates the strategy that Mike Griffin as the new AA for Exploration brings to SEI
  - Build Congressional trust by starting small and meeting cost and schedule objectives
  - Sell SEI in bite size chunks - "Buy it by the yard..."
  - Start with Robotic Missions
  - Start early with missions that are:
    - Small
    - Simple
    - Cheap
    - Quick
    - Contribute to SEI goals

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Artemis Program Rationale (Cont)

Artemis

- Analysis Stafford Synthesis Group Architecture Themes

  - Architecture 1, Mars Exploration - Meets the criteria of establishing a permanent presence of the moon, without committing to manned landings if Mars beckons irresistibly or if funding constrained

  - Architecture 2, Science Emphasis - Establishes "Lunar Network", also emplaces optical and radio observatories

  - Architecture 3, Moon to Stay... - Delivers rover for in-situ resource characterization and subsurface analysis prior to base selection

  - Architecture 4, Space Resource Utilization - Meets requirements to locate resource concentrations, map them and to test pilot processes, technologies, and equipment

Artemis Concept is Architecture independent - value varies with theme

Artemis Program Rationale (Cont)

Artemis

- Compelling scientific rationale exist for further exploring the surface of the Moon, and for using the Moon as a platform for Space and Astrophysics observatories

- Equally compelling is the need for engineering information
  - Base-site survey
  - Resource characterization
  - Hardware test or demonstration, and technology development
- Infrastructure emplacement
  - Navigation aids
  - Caches for long traverses
  - Emergency resupply
  - Remote equipment delivery

To safely extend the reach of humans to areas on the moon that are otherwise inaccessible due to cost or risk

Artemis

Summary of Potential Payloads

Sample Collection
- Sample

Geophysical Station
- Geophysical Station
- Central Station
- RTG
- Broad Band Seismometer
- Heat Flow Probe
- Long Period Seismometer
- Solar Wind Experiment
- Charged Particle Experiment
- Cosmic-Ray Experiment
- Micro-Meteorite Experiment
- Mass Spectrometer
- Suprathermal Ion Detector
- Cold Cathode Pressure Gage
- UV Spectrometer
- Alpha Particle Spectrometer
- Low Frequency Magnetometer
- Tidal Gravimeter

Rover
- Rover
- XRD/XRF
- LIBS
- Magnetometer
- Gamma-Ray Spectrometer
- Neutron Spectrometer
- Stereo-Imager
- Mass Spectrometer
- Visual and Near-IR Spectrometer

Telescopes
- 1 m APT/UV-IR Survey/UV Spec.
- UV Ast./Atm.
- Lunar Transit Telescope
- Lunar Hubble Telescope
- Moon-Earth VLBI
- VLF Interferometer

ISRU
- Cast Basalt
- O2 Extraction
- Thermal Processing
- Magnetic Separation
- Gas Analysis

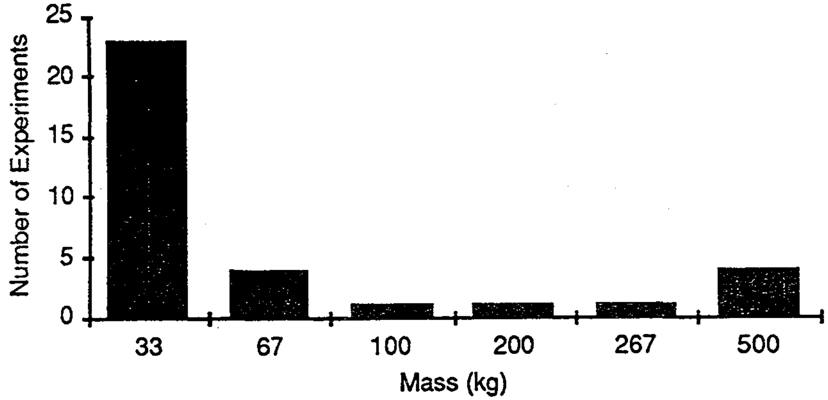
Engineering
- Melt Drill

Biology
- Soil Solution
- Cell Development

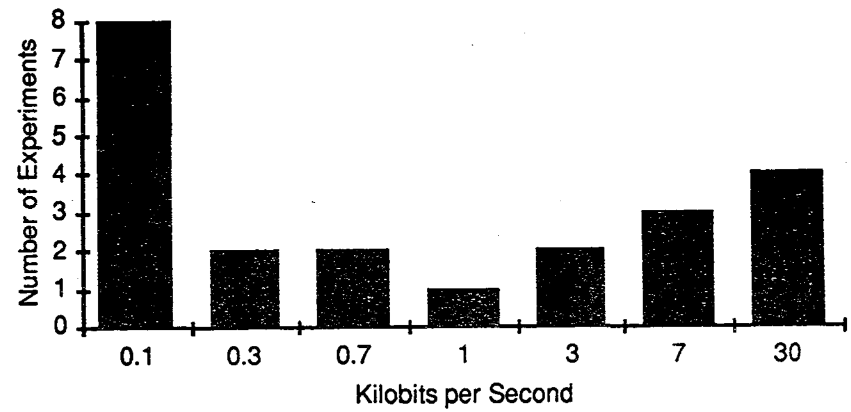
Stephen Bailey/IE3/283-5411

Physical Characteristics of Experiments

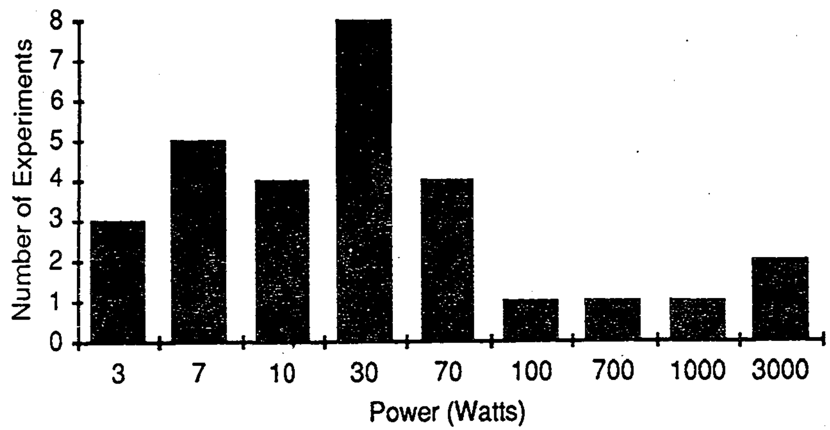
Mass of Individual Experiments



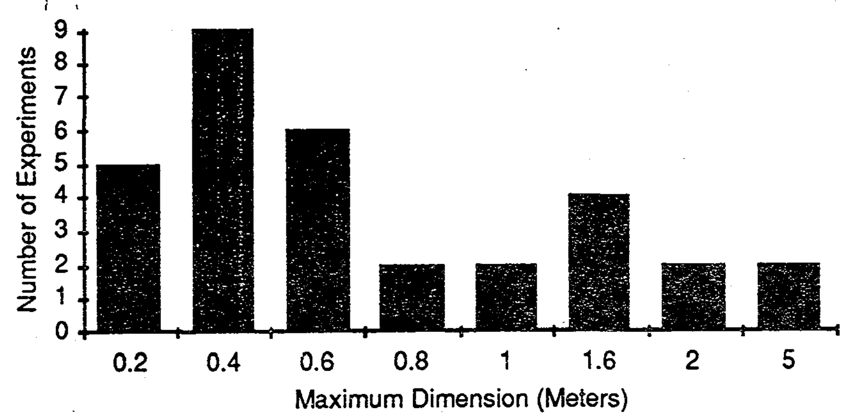
Experiment Downlink Data Rates

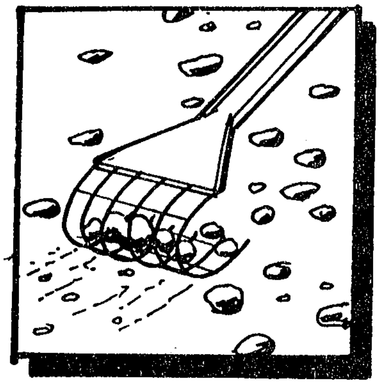


Power Requirements for Experiments

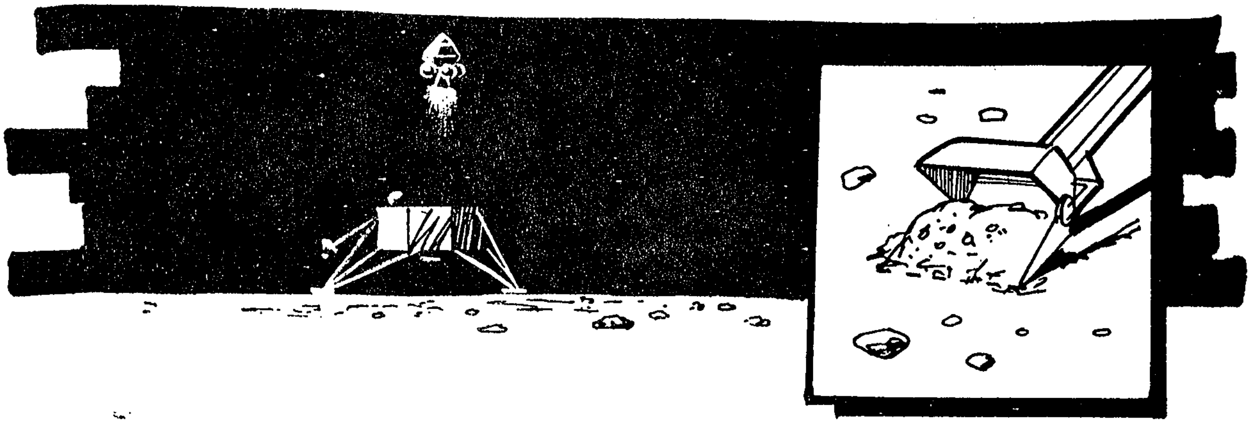


Maximum Dimension of Experimen

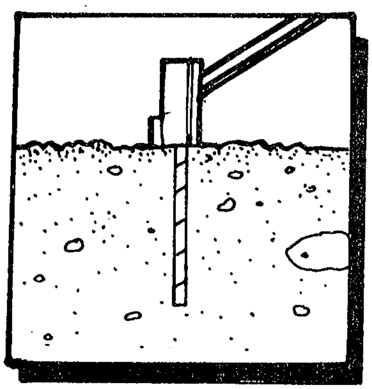




ROCK SAMPLES



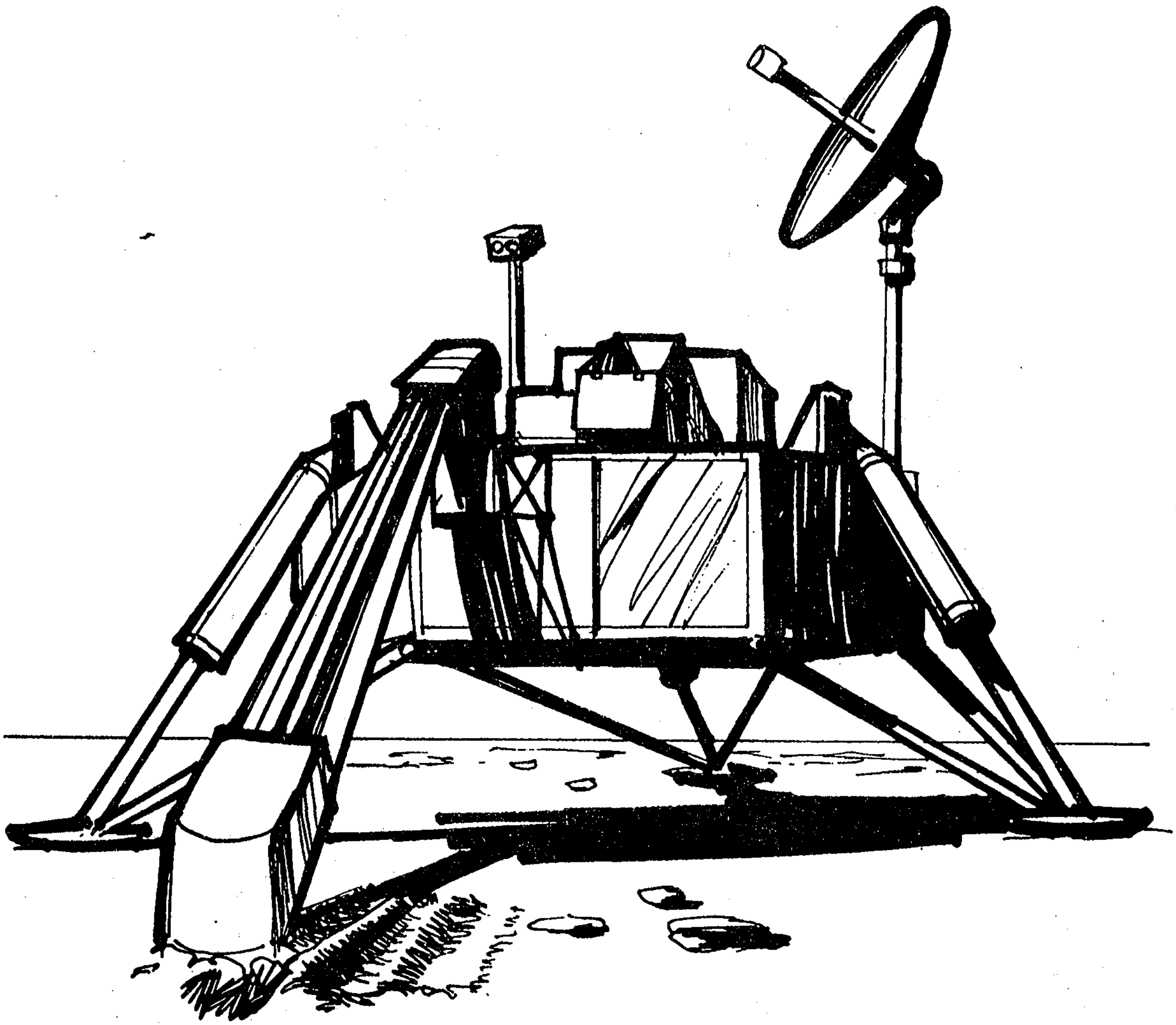
SOIL SAMPLES



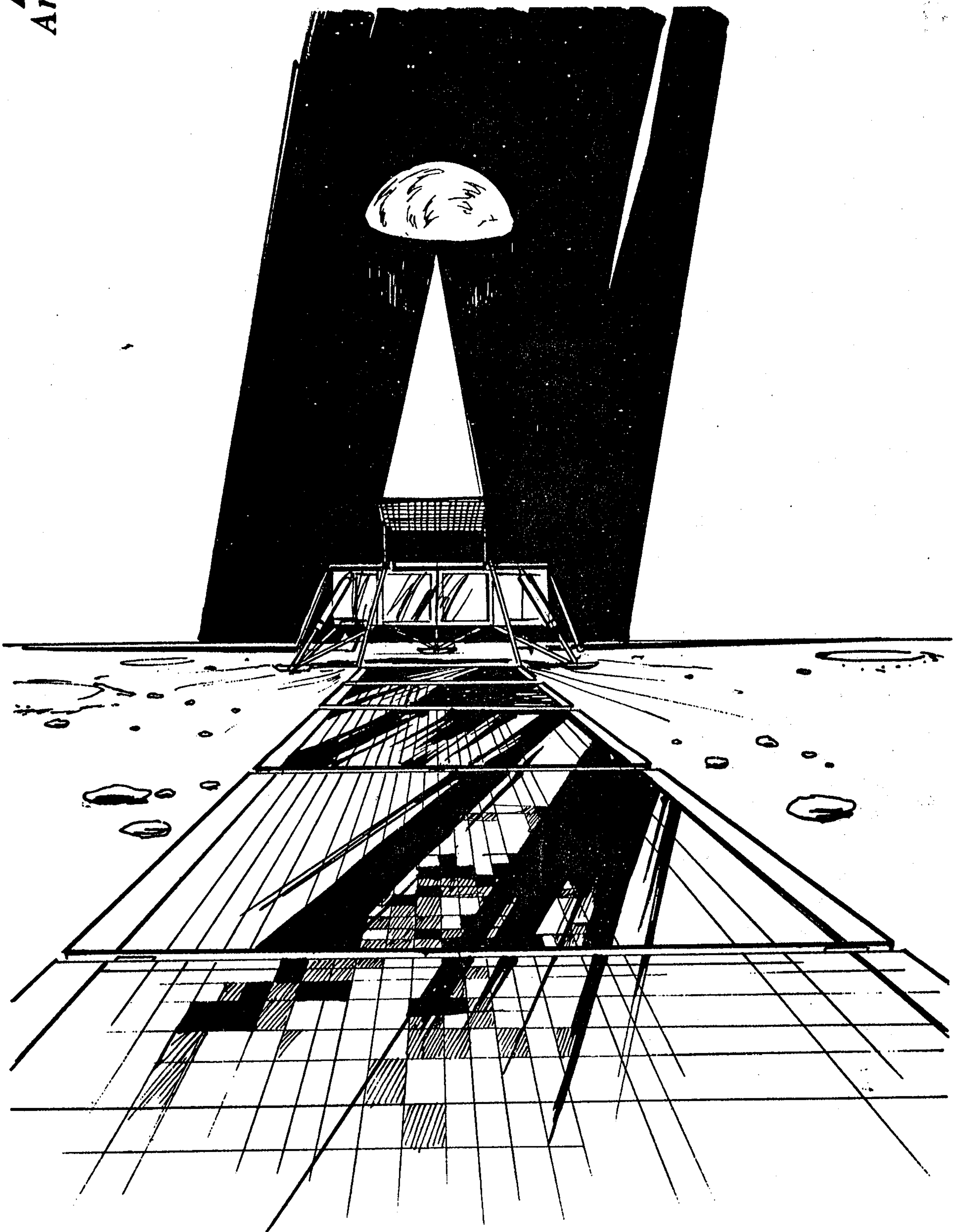
CORE DRILLING

SAMPLE RETURN MISSION

Stephen Bailey/IE3/283-5411

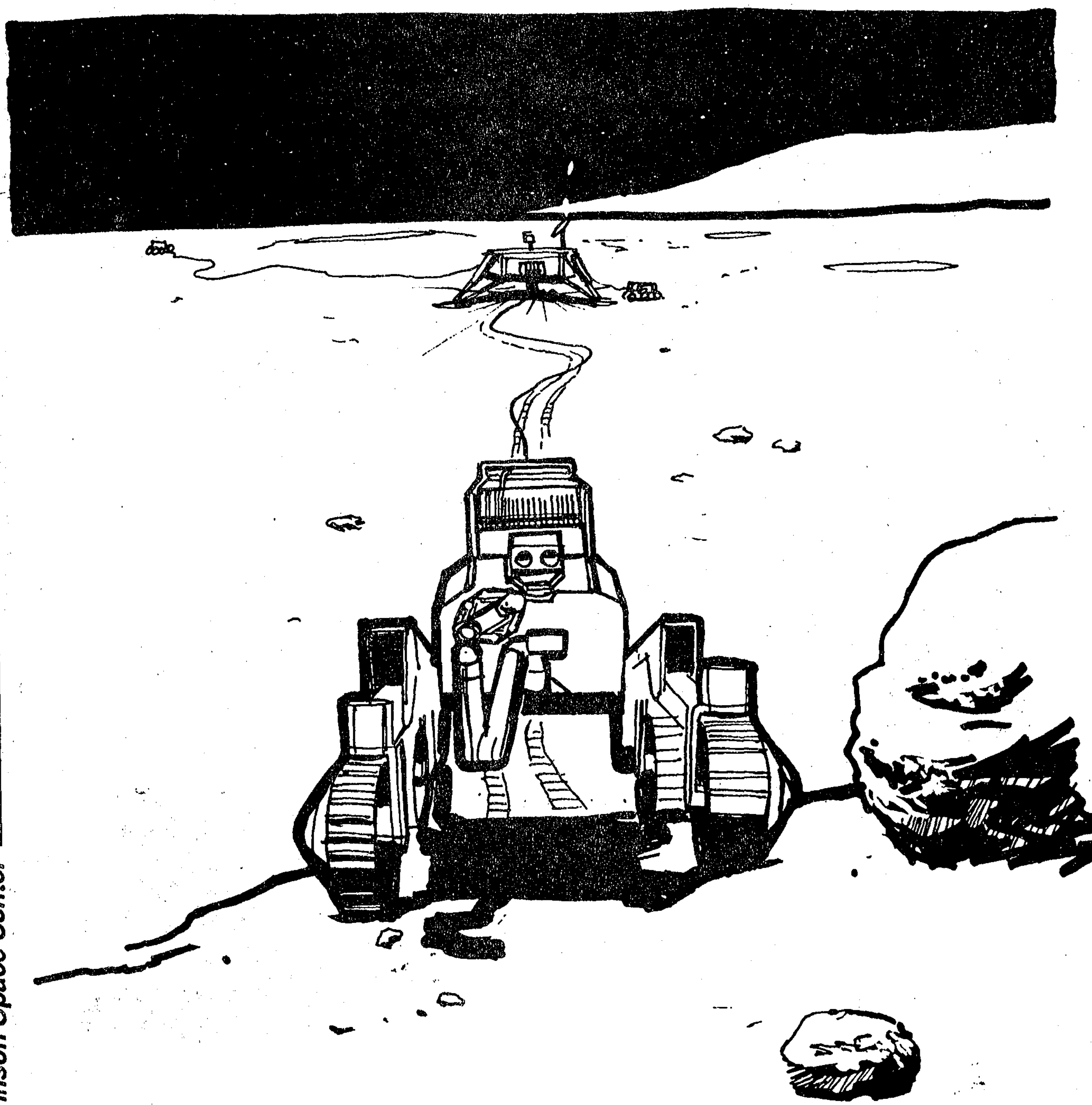


ISMU · PILOT PLANT
ON UNMANNED
LUNAR LANDER



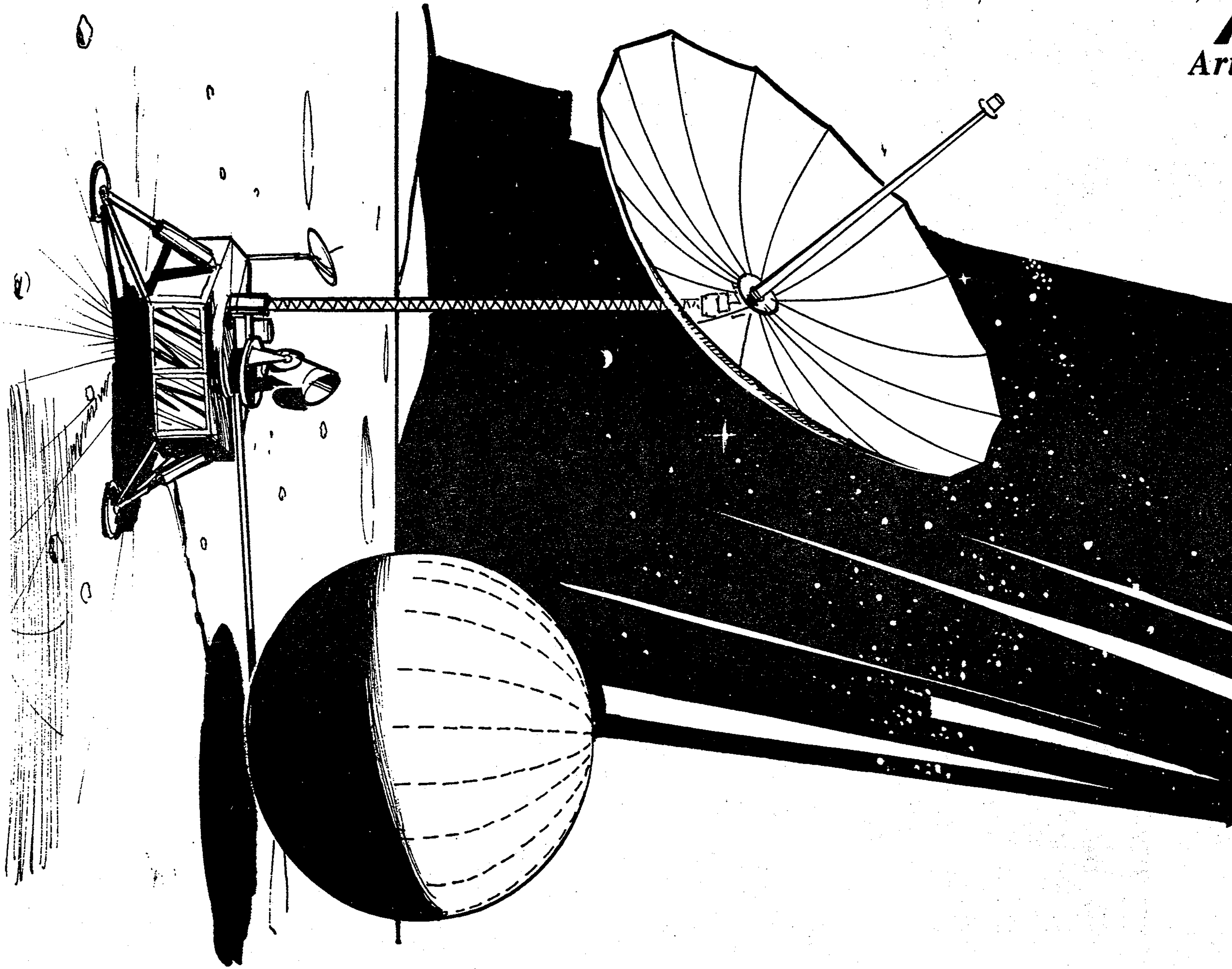
BEAMED POWER PROOF-OF-CONCEPT

Stephen Bailey/IE3/283-5411

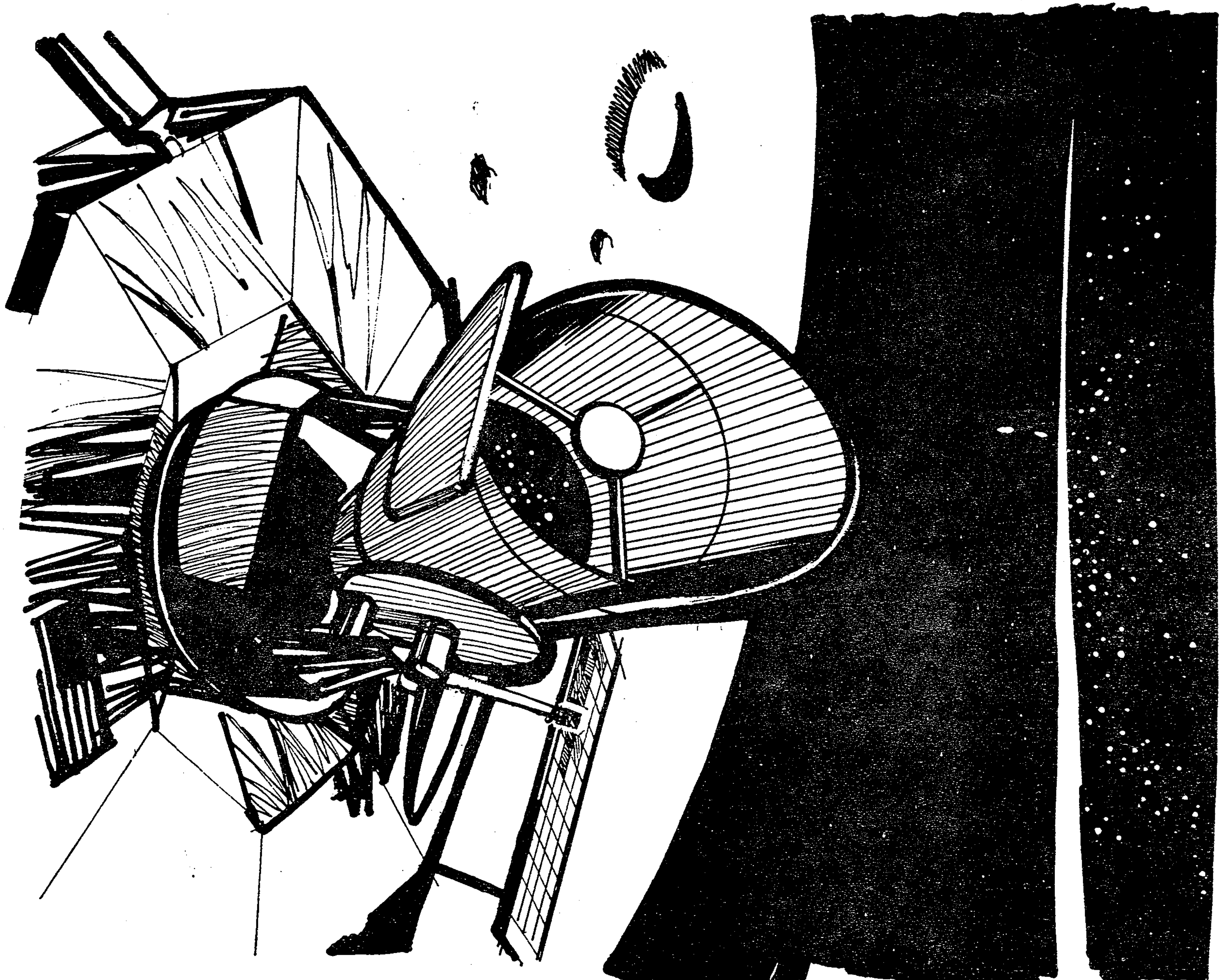


TETHERED MICRO-ROVERS

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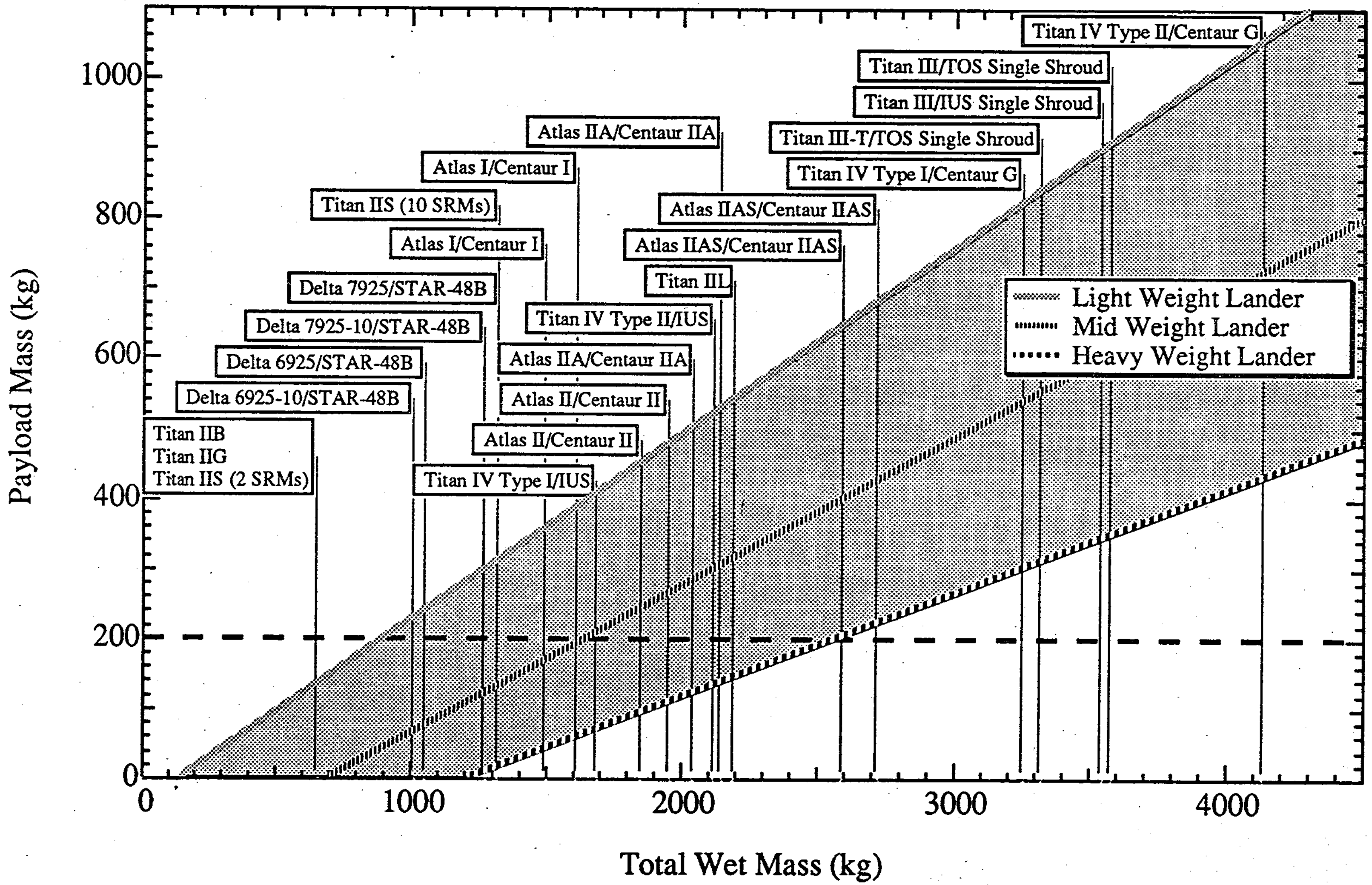
Stephen Bailey/IE3/283-5411



Stephen Bailey/IE3/283-5411

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TransLunar Injection Capability of US Launchers as a Function of Payload Delivered to the Surface



Stephen Bailey/IE3/283-5411

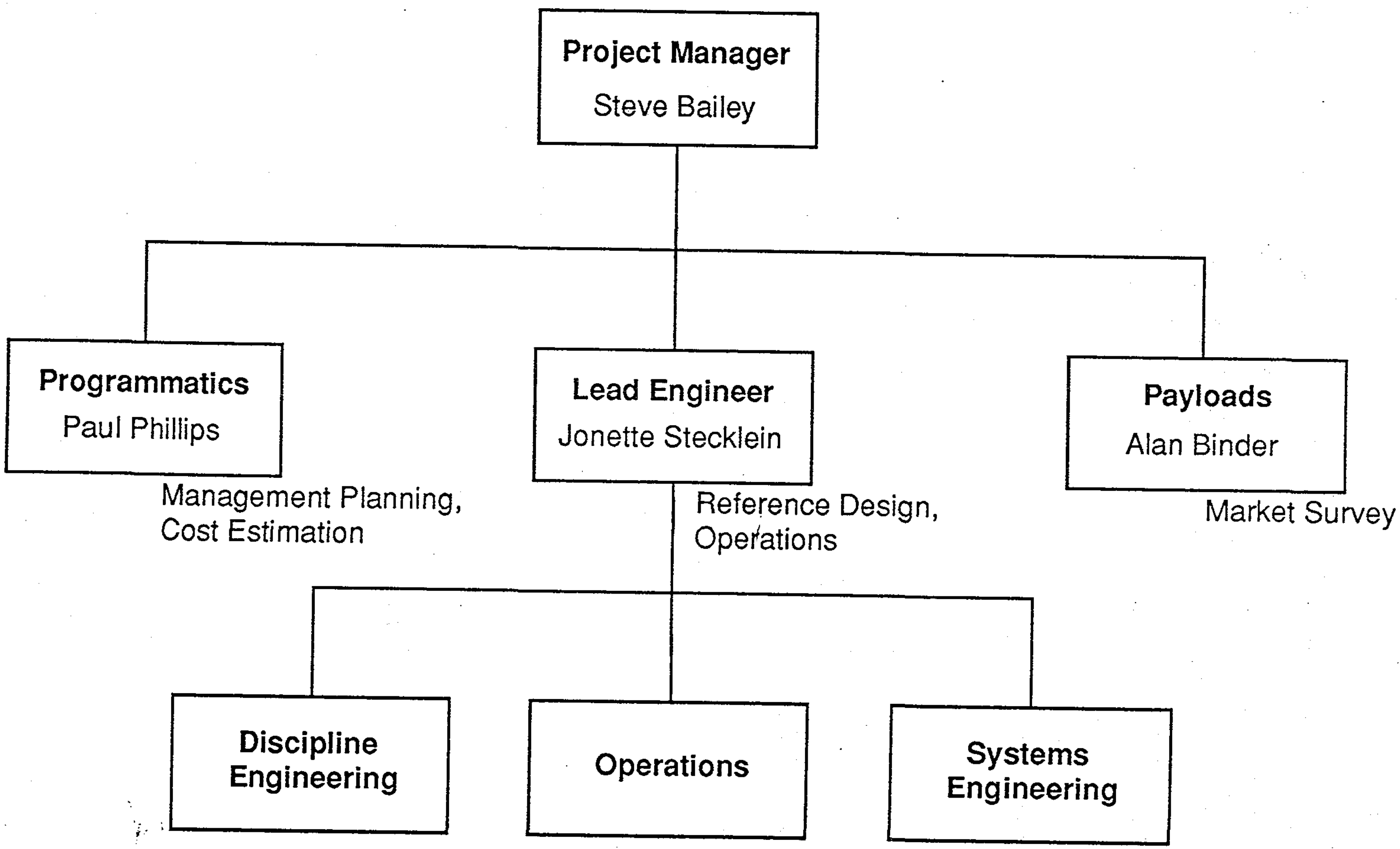
Study Objectives

Artemis

- The purpose of the design study is to define what the attributes of a lander would be that rank priorities as:
  - Cost (as low as possible)
  - Schedule (1996 launch date)
  - Performance (within reason for a potentially long lived system)
  - Risk (acceptable for this mission type)
- Provide crisp definition of lander concept for critical review by:
  - Payload Developers
  - Payload Sponsors (Codes M, R, SL, SS, SZ, SB, XE, ...)
  - Industry and other Government agencies (particularly SDIO)
- Demonstrate the ability of the center to quickly mobilize, with NIO leadership, and to efficiently produce quality study products

Stephen Bailey/IE3/283-5411

Study Team Organization



Stephen Bailey/IE3/283-5411

Study Products

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(Complete)

- Payloads Assessment
  - Market Definition
  - Interface Requirements
- Payload Integration Analysis
- Requirements
  - Lander mission and system
  - Payload Interfaces
  - Operations
- Launch Vehicle Analysis
- Subsystem Design Concepts
- System Trade Studies

(In Work)

- Cost Analysis
  - System-level Up
  - Top Down
- Ground Operations Overview
- Mission Planning/Ops. Overview
- Program Management Plan
- Procurement Plan
- Facilities Assessment
- Development/Certification/ Test Plan

Conclusions

Artemis

- Excellent support from the Center resulted in a well executed study
- In many ways a prototype for how similar preliminary concept studies can be performed
  - Fast paced, fixed schedule
  - NIO in project management role, ET in Systems Engineering role, EA providing discipline engineering
- Concept study will be finished by mid October
  - EA's work is finished
- Study objectives met
- Next phase of requirements assessment set to begin
- Accolades all around

Stephen Bailey/IE3/283-5411

Artemis

Recommendations

- Return in mid October with Programmatics assessment
  - Strategic options and recommendations
    - Program Implementation Plan
    - Procurement Strategies
    - Project Management Strategies
    - Facilities and resource assessment
- Get a more definitive reading from our customer, Mike Griffin, on the Artemis Concept
- Conduct an assessment of where to go from here
  - Options:
    - Quit until serious indication of program interest
    - Study Common Mars Lander
    - Consider In-House skunkworks
    - Other

Stephen Bailey/IE3/283-5411

The Name and the Logo

Artemis

- Should a project develop, we would like to suggest a name
  - Artemis
  - Reference from classical Greek mythology
  - Purposefully avoiding an acronym
- Artemis is the Greek Goddess often associated with the Moon
  - She is the twin sister of Apollo
  - The shining one, goddess of the golden arrows
  - The slender crescent of the Moon is her bow
- The logo represents the shaft of an arrow notched in the bow, with a "quiver" of payloads ready to loose

Stephen Bailey/IE3/283-5411

Appendix

Payload Descriptions

Payload: Sample Return

Vital Statistics
Mass: 200 kg
Power: TBD
Volume: 2m x 2m x 2m
Data Rate: TBD
No. of Missions: ~100 over 30 years
Mission Duration: Few hours on Lunar surface

Description: Collect 1 kg of 1 to 3 cm rock and soil samples. Deliver the samples to Earth via a return stage. Obtain representative samples from the numerous petrological units over the entire lunar surface.

Objective: Determine the composition, the age and developmental history of the lunar crust and mantle and the Moon itself. Find economically important resources for use on the Moon and for export to Earth.

Stephen Bailey/IE3/283-5411

Payload: Geophysical Station Network

Vital Statistics
Mass: 150 kg
Power: 45 w
Volume: 1.6m x 1.2m x 1.2m
Data Rate: 1.1 kbs
No. of Missions: >20
Mission Duration: >10 years

Description: Set up a global network of geophysical stations to obtain long term, seismic, heat flow, magnetic, exospheric, gravity, etc., data on the Moon.

Objective: Determine the internal structure, composition, energy budget, etc., of the Moon. Determine the composition and dynamics of the lunar atmosphere.

Stephen Bailey/IE3/283-5411

Payload: Teleoperated Rovers

Vital Statistics
Mass: 200 kg
Power: 300 w
Volume: 2m x 2m x 2m
Data Rate: 25 kbs
No of Missions: ~10
Mission Duration: ~1 year

Description: Obtain composition, gravity, magnetic, etc. profiling data along 100 to 1000 km traversers. Do detailed resource mapping of 1 to 10 km square areas.

Objective: Determine the variations in the composition and structure of the crust on the regional scale to determine its origin and evolution. Determine the extent and ore grade of lunar mining sites.

Stephen Bailey/IE3/283-5411

Payload: 1m Astronomical Telescopes

Vital Statistics
Mass: 200 kg
Power: TBD
Volume: 2m x 2m x 2m
Data Rate: TBD
No. of Missions: ~10
Mission Duration: >10 year

Description: Set up several 1m, automated telescopes. Obtain high quality, uninterrupted, long term, UV, visual and IR, photometric, spectral and sky survey data.

Objective: Determine the composition, structure and evolution of stars, galaxies and the universe as a whole.

Payload: Moon-Earth Radio Interferometer

Vital Statistics
Mass: 200 kg
Power: TBD
Volume: TBD
Data Rate: TBD
No. of Missions: 1
Mission Duration: > 10 years

Description: Set up a radio telescope on the Moon as part of a Moon-Earth interferometer with a 384,000 km baseline (30 x greater than possible on the Earth alone).

Objective: Obtain detailed astrometry with a resolution of 30 microarcsec (at 6 cm wavelength).

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Payload: Very Low Frequency Radio Antennas

Vital Statistics
Mass: 20 kg
Power: 20 w
Volume: TBD
Data Rate: TBD
No. of Missions: > 20
Mission Duration: > 10 years

Description: Set up an array of 1 to 10 mHz antennas to obtain the low frequency radio spectra of galactic and extragalactic sources.

Objective: Determine the structure of galactic and extra-galactic objects. Map the distribution of interstellar matter out to several thousand parsecs.

Stephen Bailey/IE3/283-5411

Payload: Lunar Polar Crater Telescope

Vital Statistics
Mass: 200 kg
Power: TBD
Volume: 2 m x 2 m x 2 m
Data Rate: TBD
No. of Missions: 1
Mission Duration: > 10 years

Description: Set up a 1 m, automated, IR telescope in a permanently shadowed, polar crater where the temperature is always < 80k.

Objective: Obtain IR data on solar system, galactic and extra-galactic sources with a telescope and detector which are naturally cooled in the lunar polar environment.

Stephen Bailey/IE3/283-5411

Artemis

Payload: Lunar Resource Utilization Experiments

Vital Statistics
Mass: 200 kg
Power: TBD
Volume: TBD
Data Rate: TBD
No. of Missions: > 10
Mission Duration: 1 year

Description: Set up laboratory scale experiments to make lunar oxygen, cast basalt, metals, ceramics, etc. from lunar resources.

Objective: Evaluate various processes proposed for obtaining useful products from lunar resources.

Stephen Bailey/IE3/283-5411

Artemis

Payload: SEI Engineering Experiments

Vital Statistics
Mass: 200 kg
Power: TBD
Volume: TBD
Data Rate: TBD
No. of Missions: > 10
Mission Duration: 1 year

Description: Conduct engineering tests of equipment in the lunar environment.

Objective: Determine the effects on SEI critical hardware of lunar dust, 1/6g, vacuum, etc.

Stephen Bailey/IE3/283-5411

Payload: Biological Experiments

Vital Statistics
Mass: < 200 kg
Power: TBD
Volume: TBD
Data Rate: TBD
No. of Missions: ~ 3
Mission Duration: 1 year

Description: Set up small, automated biological experiments in the lunar environment.

Objective: Determine the effects of 1/6g, cosmic radiation, etc. on the growth and health of simple plants and animals.

Stephen Bailey/IE3/283-5411

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Artemis

Common Lunar Lander

Engineering Study Results

Presentation to Aaron Cohen

September 17, 1991

by

Jonette Stecklein

Artemis

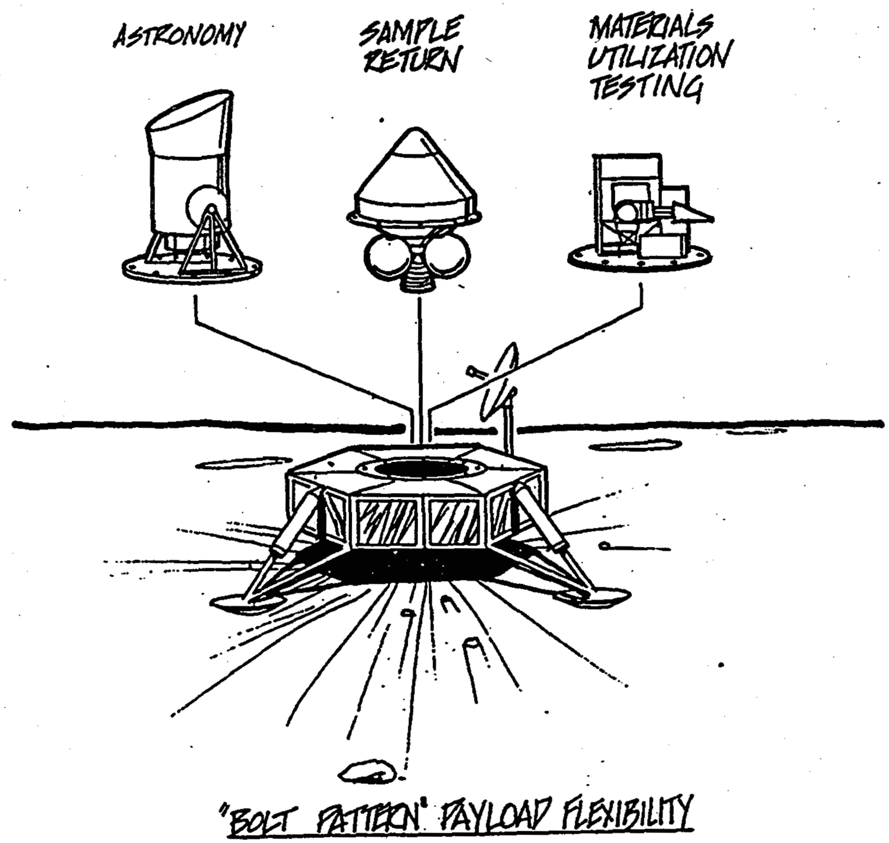
CLL Engineering Study: Results

- CLL Engineering Study
- CLL Mission
- Options
- CLL Team & Supporters

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Mission

Provide a delivery system to soft-land a 200 kg payload set at any given Lunar latitude and longitude.



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CLL Engineering Study

Objective : Perform a feasibility study of the CLL concept

Approach : Point design of lunar lander + Overall system trades

Products : Requirements for delivery system

(launch vehicle, lander, payload i/f, mission op.)

Completion and documentation of major system trades

Lunar lander conceptual design and drawings

Subsystem design and characterization (lunar lander)

Cost estimates at the subsystem level (lunar lander)

J. Stecklein
9/16/91

Common Lunar Lander
Engineering Study Schedule

Month	Mon.	Tues.	Wed.	Thurs.	Fri.
July 1991			KICKOFF MTG 17	18	19
July 1991	22	23	24	25	1ST TEAM INPUT 26
July 1991	29	30	31	1	2
August 1991	5	Team Mtg 6	7	8	Power rqmts to Betsy 9
August 1991	12	Team Mtg 13	LAUNCH VEHICLE CHOSEN 14	PAYLOAD INTEGRATION COMPLETED 15	Subsystem Chosen 16
August 1991	LANDER ARCHITECTURE COMPLETED ← SUBSYSTEM INTEGRATION → 19	Team Mtg 20	21	Dry Run 22	SENIOR BOARD REVIEW 23
August 1991	26	Team Mtg 27	28	29	Trip to D.C. 30
September 1991	Holiday	3	Team Mtg 4	5	Subsystem Charac to Jonette 6
September 1991	← SUBSYSTEM INTEGRATION → 9	Team Mtg 10	11	12	Dry Run 13
September 1991	16	COHEN 2 - 4 pm B.1; Rm 945 17	9 weeks from Study Kickoff		

Artemis

Mission Goals and Requirements

GUIDELINES	→	SYSTEM DRIVERS
- Small, simple, cheap, & quick	→	① Cost ② Schedule ③ Performance

Earth Launch

- Use existing launch vehicle (medium class)
- First flight: Nov. 1996
- 2 to 5 flights/year for 20 years

Lander

- Lander provides no services to the payload (other than landing)
- Lander is active until touchdown + time to telemeter landing information
- Design loads and limits are constrained by launch vehicle, not by lander system
- Budget: $30 million/each for Lander hardware (recurring cost)

Payload Imposed Requirements

- Provide unobstructed hemispherical view of the sky
- Do not preclude payload access to lunar surface OR payload dismount
- Do not preclude payload return to Earth (Sample Return Mission)

Lander Subsystems

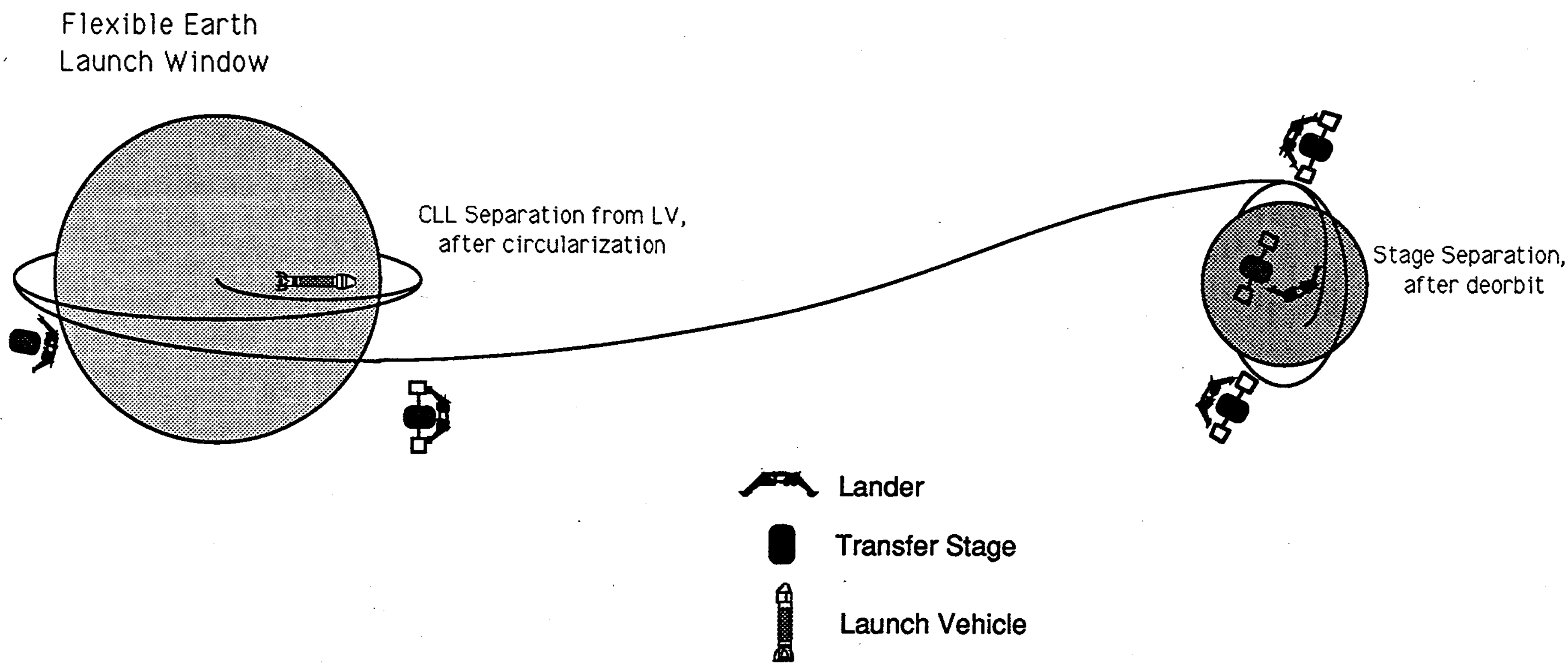
- Emphasis on choosing existing system, rather than new design
- Subsystem hardware delivery by Oct. 1993 (now Oct. 1994)
- Strive for light weight solutions
- Avoid block redundancy when a single string system can provide adequate reliability

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CLL Reference Mission

- Payload set mated to pallet. CLL spacecraft built in parallel. Payload pallet and CLL spacecraft integrated (structural i/f only).
- CLL 2 stage spacecraft is launched by ELV using an east coast launch pad.
- LV places CLL in circular Earth orbit..
- CLL remains in Earth orbit for up to 1 rev.
- CLL Transfer Stage performs TLI.
- 5 day trip to moon.
- Transfer Stage performs LOI, into circular orbit about Moon.
- Up to 14 day wait in lunar orbit.
- Transfer Stage performs deorbit burn.
- Transfer Stage separates from Lander Stage.
- Lander performs descent and landing burns, targeting for a given lunar lat/long, and landing at lunar dawn.
- Lander transmits final system performance and landing location information to Earth. Sized for 1 hour lifetime on lunar surface.

CLL Mission



Flexible Earth
Launch Window
CLL Separation from LV,
after circularization
Stage Separation,
after deorbit
Lander
Transfer Stage
Launch Vehicle

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Launch Vehicle

- Purchase
  - medium class ELV
- Options
  - Delta II
  - Titan II Series
  - Atlas II Series

Transfer Stage

- Preliminary Sizing
- 86.5% Mass Fraction
  - 7.6% prop. sys. (dry)
  - 5.9% structure, etc.
- Subsystems off-loaded from Lander Stage

Lander Stage

- Designed through subsystem level
- Subsystems designed
  - Structure
  - Propulsion
  - Power
  - GN&C
  - Communication
  - Tracking
- Subsystems estimated
  - Thermal
  - Insulation

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Cost

	Recurring Costs	Non-recurring Costs
• Launch Vehicle	$ 50 - 100 million	
• CLL System		
• Transfer Stage	$ 10 million	$ 40 million
• Lander Stage	$ 30 million	$120 million

- Payloads
  - Separate program.
  - Specific costs are payload specific.

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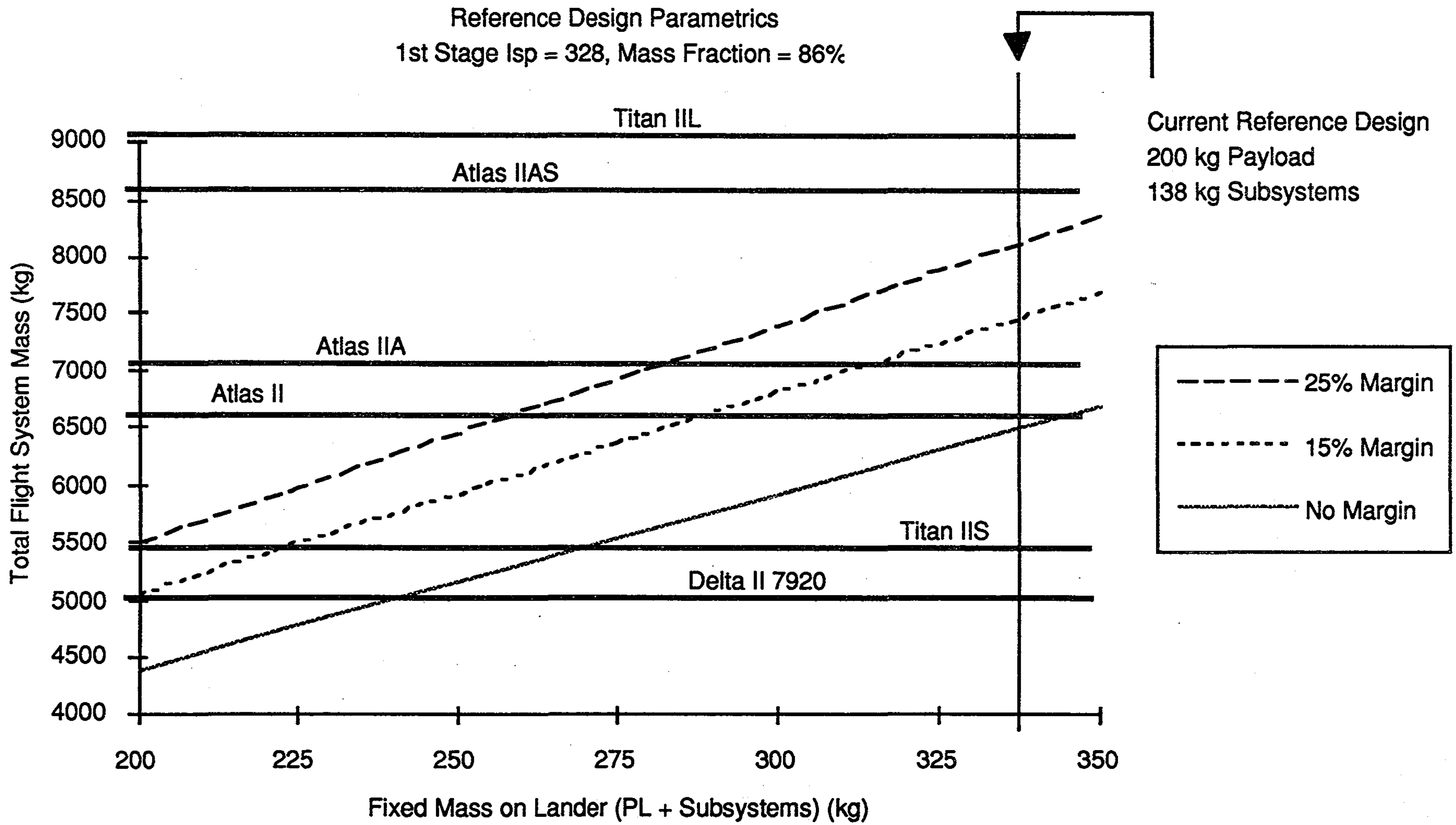
CLL Options

- Architectural Options
  - 1 stage CLL Vehicle (LOI, DD&L)
  - 2 stage CLL Vehicle
    - considered staging opportunities within (0 - 100% TLI, LOI, DD&L) burns

- Lower Cost Options
  - Lower Performance Launch Vehicle
  - Use of Refurbished ICBM Missiles (Titan II)

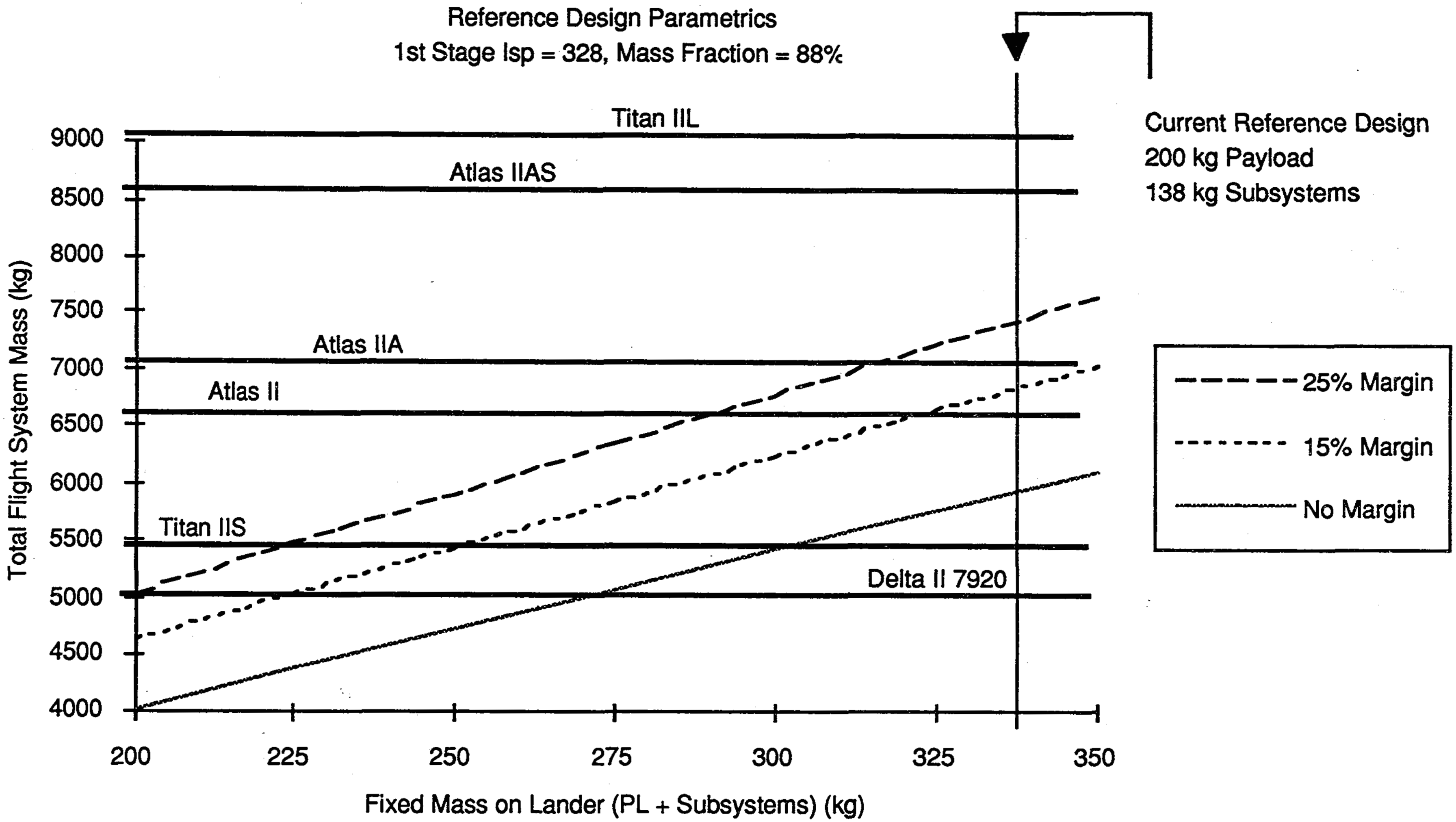
- Lower Weight Options
  - Use of SDIO Developed Hardware
  - Full Sun Trajectory during Lunar Orbit Wait
    - leads to smaller Solar Arrays

Two Stage Performance Analysis
1st Stage Mass Fraction = 0.86



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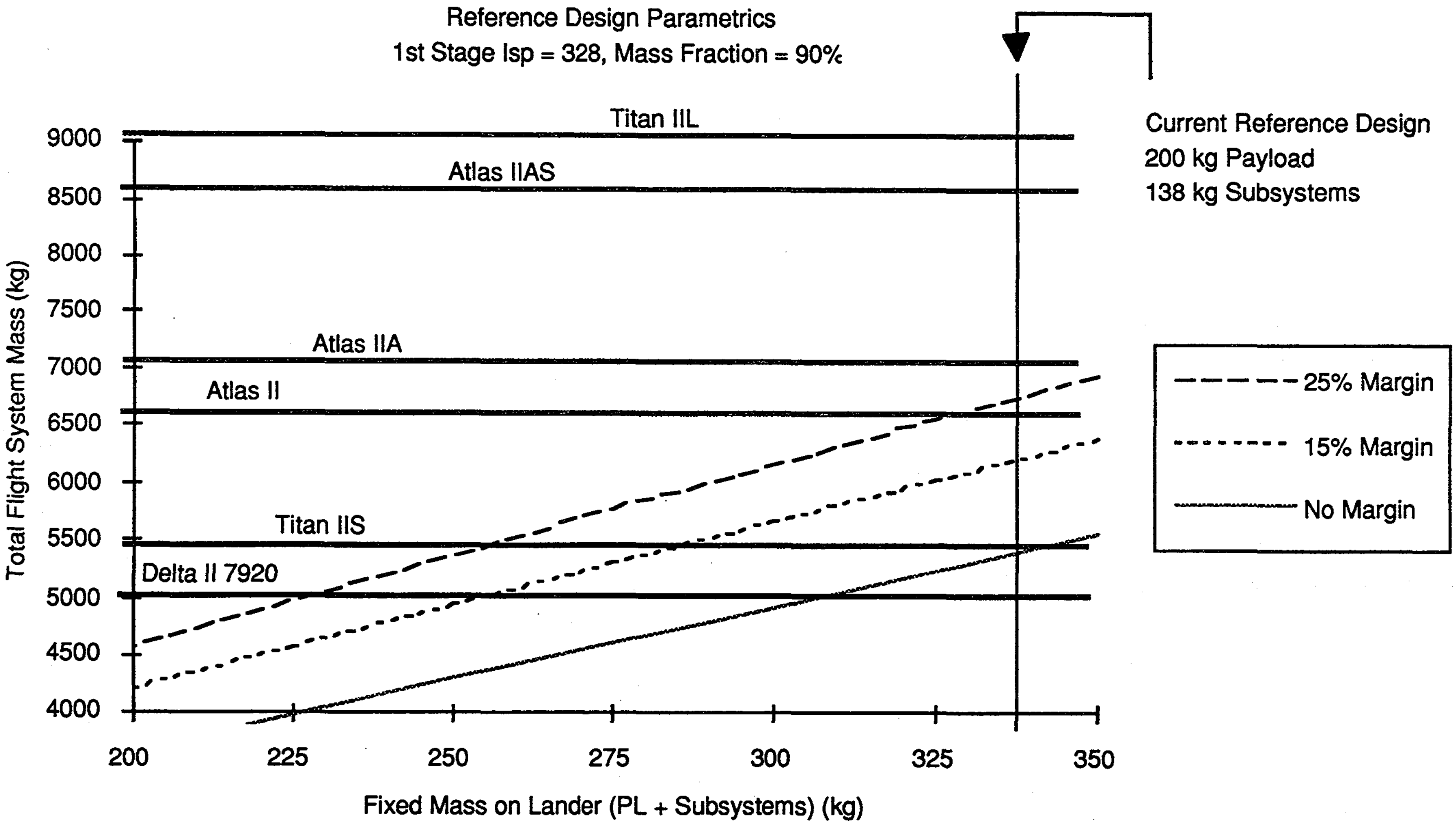
Two Stage Performance Analysis (Cont)
1st Stage Mass Fraction = 0.88



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Artemis

Two Stage Performance Analysis (Cont)
1st Stage Mass Fraction = 0.90



Artemis

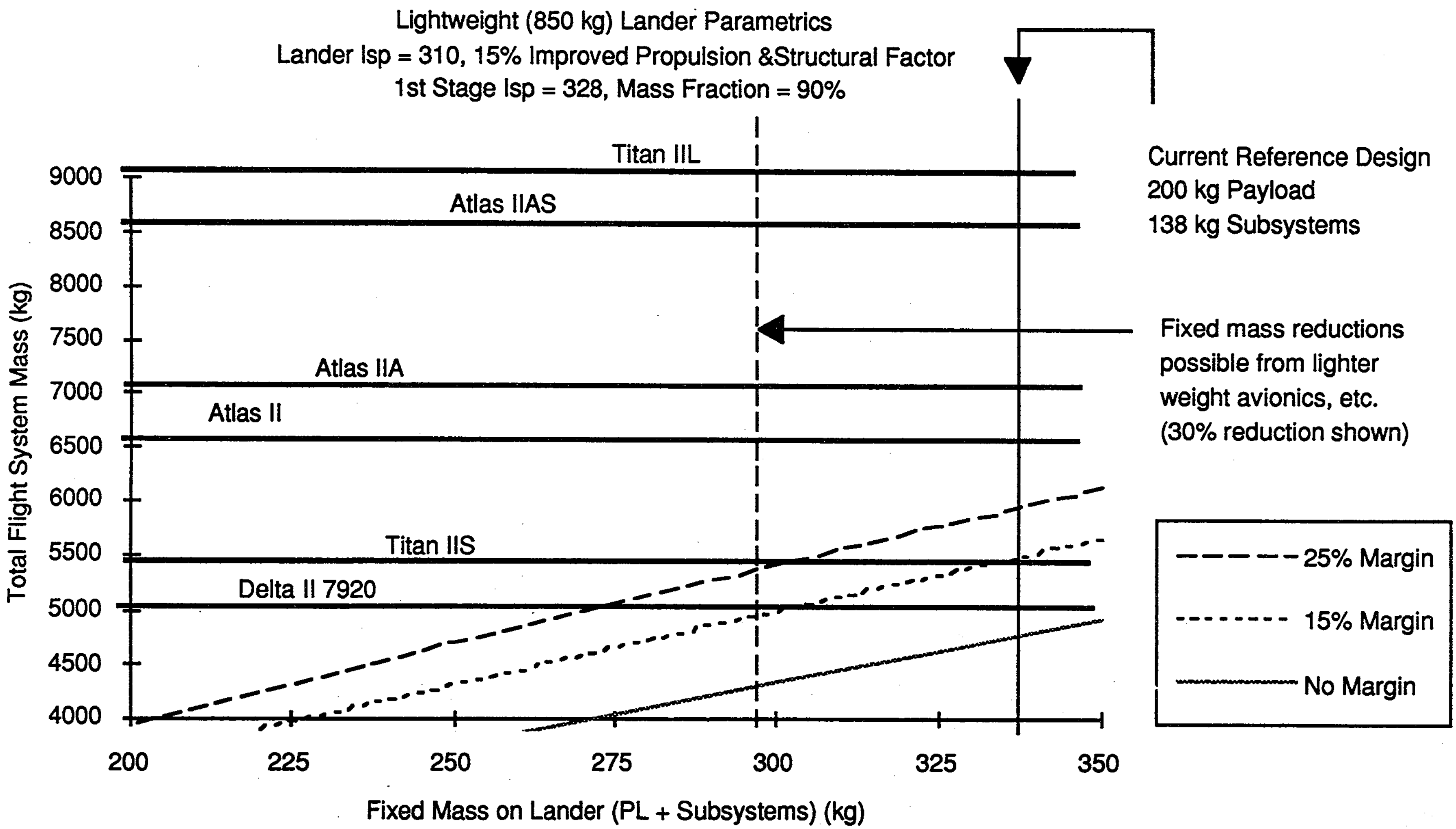
CLL Engineering Team

Jonette Stecklein	ET2	Lead Engineer
Shelby Lawson		Configuration Design
Ed Robertson		Launch Vehicle Assessment
Lynn Wagner	ET3	Trajectory Design
Bill Culpepper	EE6	Tracking
Henry Chen	EE7	Communications
Nancy Smith	EG2	GN&C
Don Hyatt	EP4	Propulsion
Betsy Kluksdahl	EP5	Power
George Sanger	LESC	Structures
Ken Baker	ER2	Landing:Hazard Avoidance

CLL Team Supporters

John Kowal	Thermal Control
Nancy Wilks	Mission Analysis
Gerry Condon	Mission Analysis
Max Kilbourn	Mission Analysis
Rocky Duncan	Mission Analysis
D. Mclain	Communication
T. Early	Communications
Zafar Taqvi	Communications
Rich Schoenberg	Propulsion
Bob Hendrix	Power (EPDC)
Darin McKinnis	Power (Pyrotechnics)
Shannan Fisher	Power (Solar Arrays)
Don Allison	Power (Solar Arrays)
Bob Bragg	Power (Batteries)
Fred Abolfathi	Structures
Rick Deppisch	GN&C
Paul Phillips	Programmatics
Steve Hoffman	Cost Estimation
Gail Boyes	Procurement
Alan Binder	Payloads/Science
W. Holdenbach	Payloads Assessment
Jim Engler	GN&C
D. McSweeny	Operations
D.McLaughlin	SR&QA
Edmund Hack	Landing

Two Stage Performance Analysis (Cont)
1st Stage Mass Fraction = 0.9, 850 kg Reference Lander



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COMMON LUNAR LANDER TRAJECTORY ANALYSIS

Lynn A. Wagner, Jr.
Nancy A. Wilks
Mission Definition Branch/ ET3
September 17, 1991

COMMON LUNAR LANDER TRAJECTORY REQUIREMENTS

- Earth launch flexibility
  - 14-day launch window to be achieved by variable loiter time in lunar parking orbit
- Land at any specified lunar latitude and longitude
- Land at any specified time in the lunar day/night cycle
- Program will operate during the entire 18.6 year lunar cycle

Lynn Wagner/ET3/x33816

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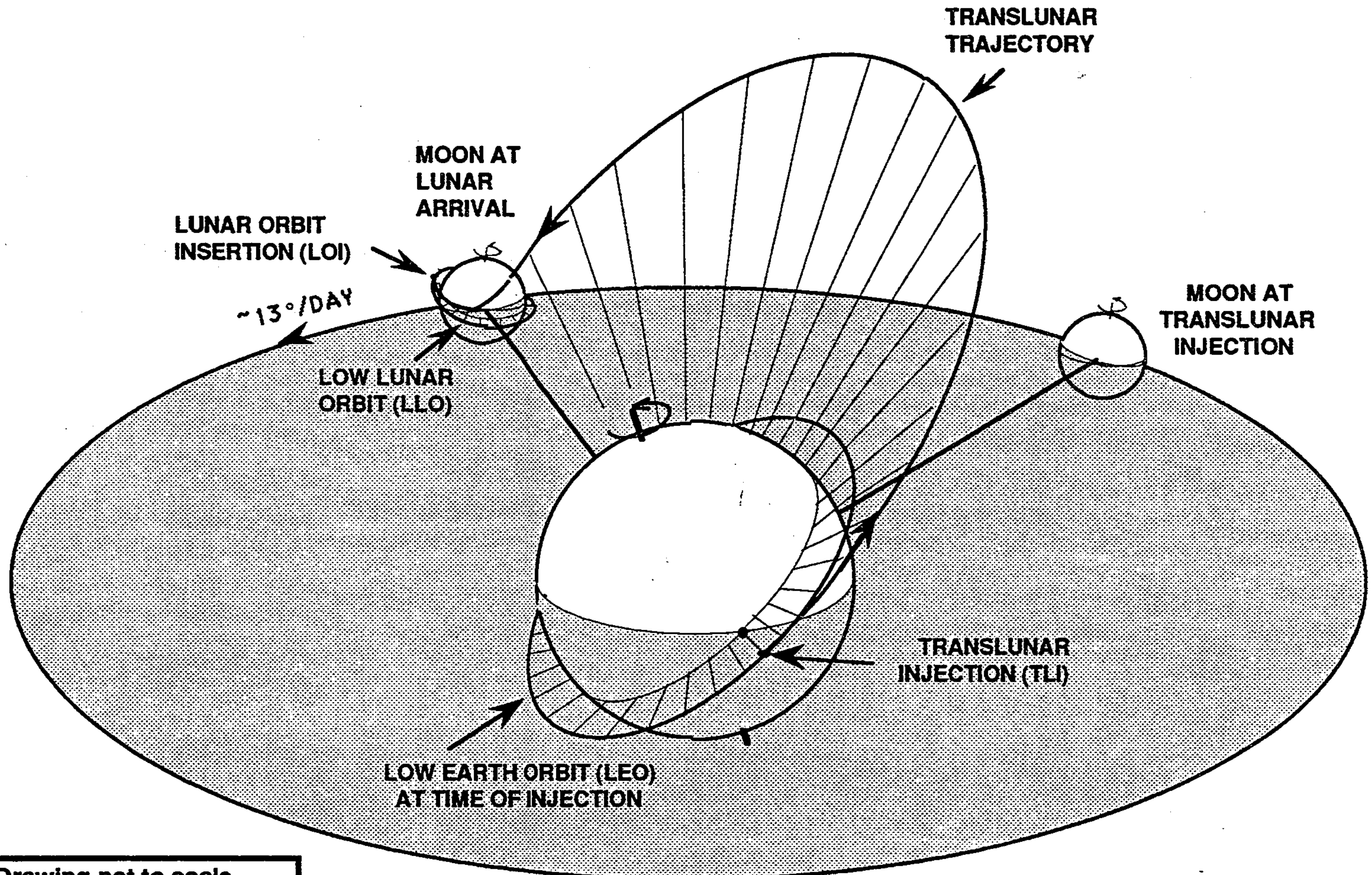
COMMON LUNAR LANDER TRAJECTORY CHARACTERISTICS

- Earth Parking Orbit (185 km circular orbit)
  - Due east launch from ETR into a 28.45 deg inclination
  - Standard circular orbit for the launch vehicles examined
- Minimum Energy Trajectories
  - 5 day transfer time
  - Near Hohmann transfers
- Lunar Parking Orbit (122 km circular orbit)
  - Minimizes deorbit, descent , and landing delta-V cost
  - Inclination and Ascending Node defined for each specific landing site and lunar loiter time
- All lunar landing sites are accessible

Lynn Wagner/ET3/x33816

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COMMON LUNAR LANDER TRAJECTORY

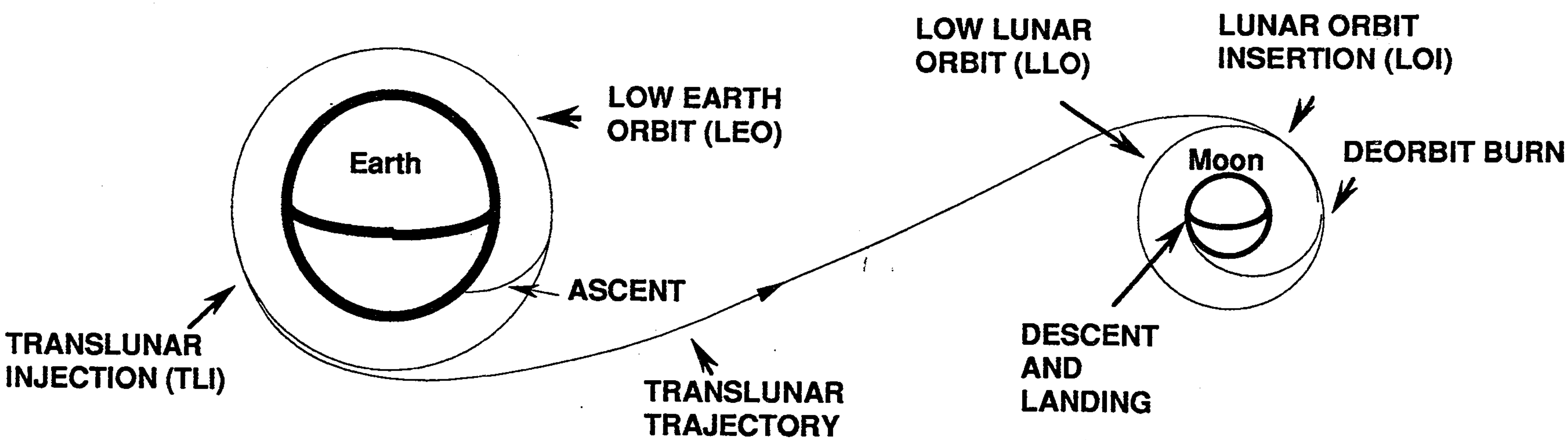


Drawing not to scale

Lynn Wagner/ET3/x33816

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COMMON LUNAR LANDER TRAJECTORY



Drawing not to scale

Lynn Wagner/ET3/x33816

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COMMON LUNAR LANDER TRAJECTORY TIMELINE

TRAJECTORY EVENT	DURATION	ALLOCATED DELTA-V *	COMMENTS
Launch	20-30 min		
Earth Parking Orbit Coast	0-90 min		185 km Circular Orbit
Translunar Injection		3200 m/s	
Translunar Coast	5 days	30 m/s	Midcourse correction (100% lighting)
Lunar Orbit Insertion		840 m/s	
Lunar Parking Orbit Coast	0-14 days		122 km Circular Orbit (Minimum of 61% lighting)
Deorbit Maneuver		30 m/s	
Deorbit Coast	51 min		122 x 15 km Orbit
Descent and Landing	9 min	1820 m/s	

* Does not include provisions for dispersions and performance reserves

Lynn Wagner/ET3/x33816

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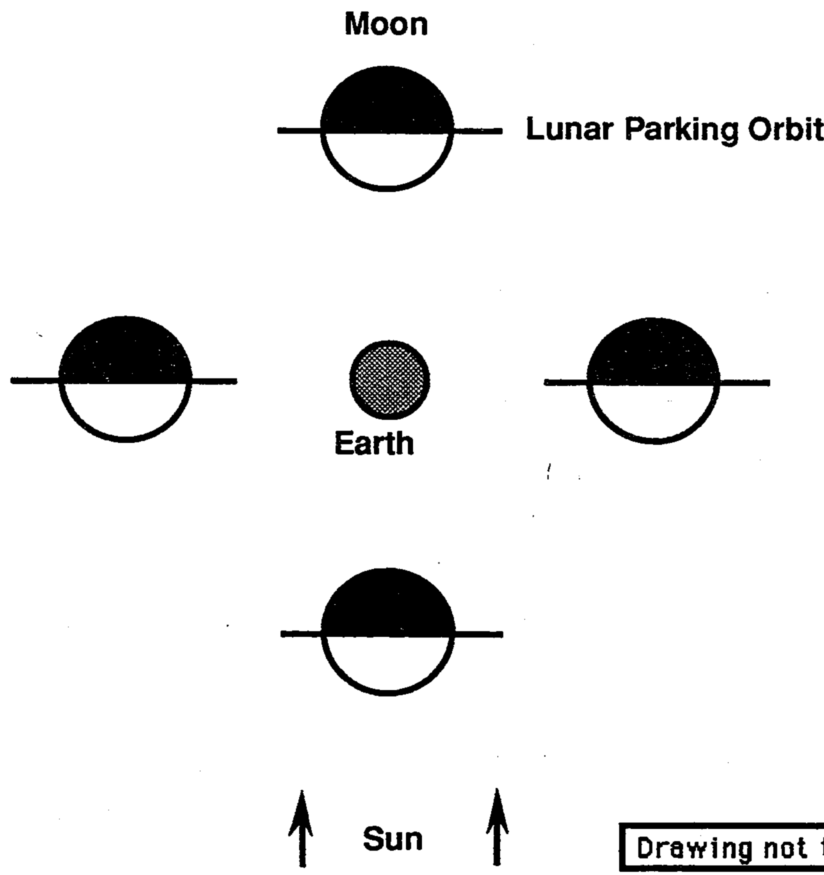
COMMON LUNAR LANDER ALTERNATE TRAJECTORY

- SCENARIO
  - 90° Inclination Orbital Plane required
  - 122 km. Circular Orbit
  - Approximately 90° or - 90° Ascending Node location at LOI
- ADVANTAGES
  - 100% light during entire lunar orbit
  - Minimum batteries needed during lunar orbit coast
- DISADVANTAGES
  - Solar Panel shadowing may occur during translunar coast and maneuver/IMU realignments
  - Launch Windows occur once or twice a month
    - The landing site determines which opportunity is valid based on the maximum lunar orbit loiter time
    - The lighting constraints allowable are sunrise and sunset
  - Launch Window duration is estimated at 2-3 days at most

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COMMON LUNAR LANDER ALTERNATE TRAJECTORY



Drawing not to scale

Lynn Wagner/ET3/x33816

U.S. Gov't

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Introduction

Baseline Mission Profile:

ELV injection to a 185 km circular LEO

Two-stage lunar stack consisting of a transfer vehicle and lander

Baseline ELVs:

Delta II 7920

Titan IIS SLV

Optional Mission Profile:

ELV performs TLI burn

Single-stage lander injected

Optional ELVs:

Atlas II, IIA, IIAS

Titan IIL SLV

McDonnell Douglas 7920

Description of Delta II Series ELVs:

LOX/RP-1 first stage, RS-270/B or RS-270/C main engine.

N2O4/Aerozine-50 second stage, AJ10-118K, avionics for first two stages.

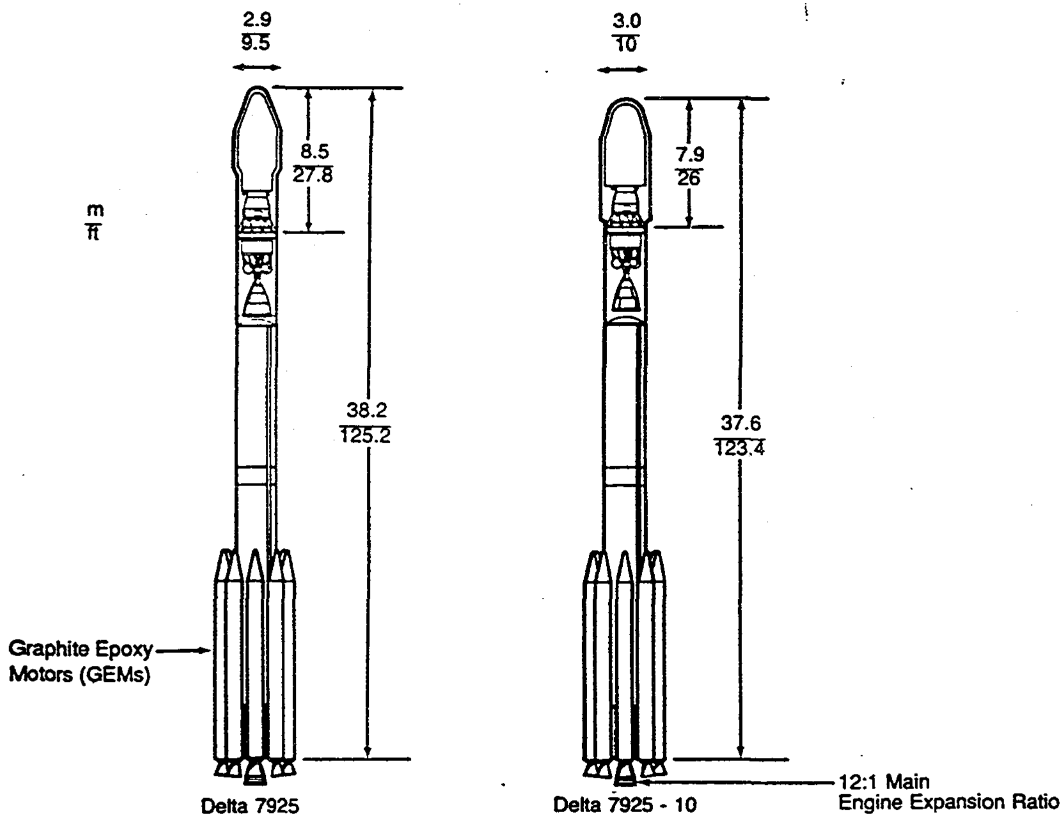
Delta II 7920 has 9 GEM strap-ons, 7925 has a STAR-48B upper stage.

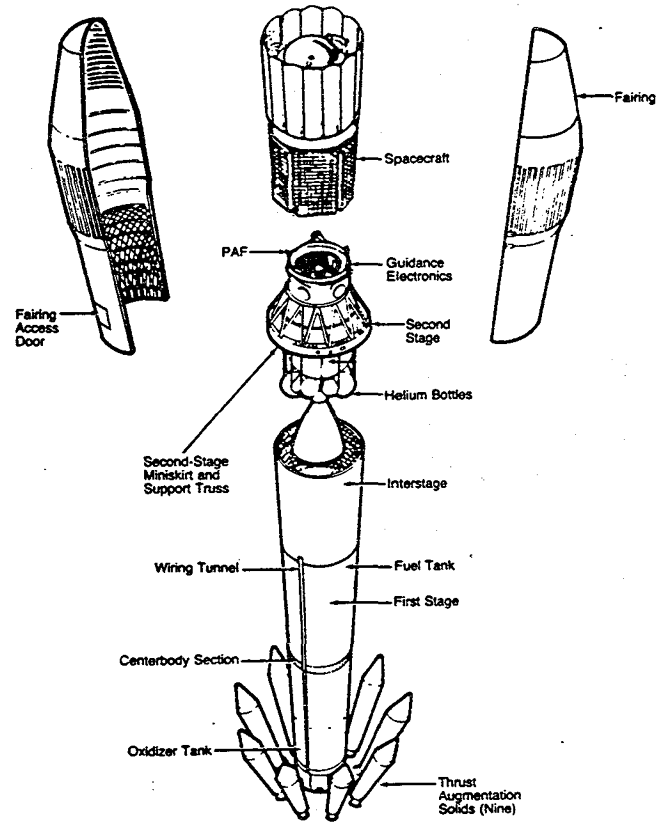
Availability:

Production Plans: Phase out from 69xx to 79xx series complete by 1992.

Artemis

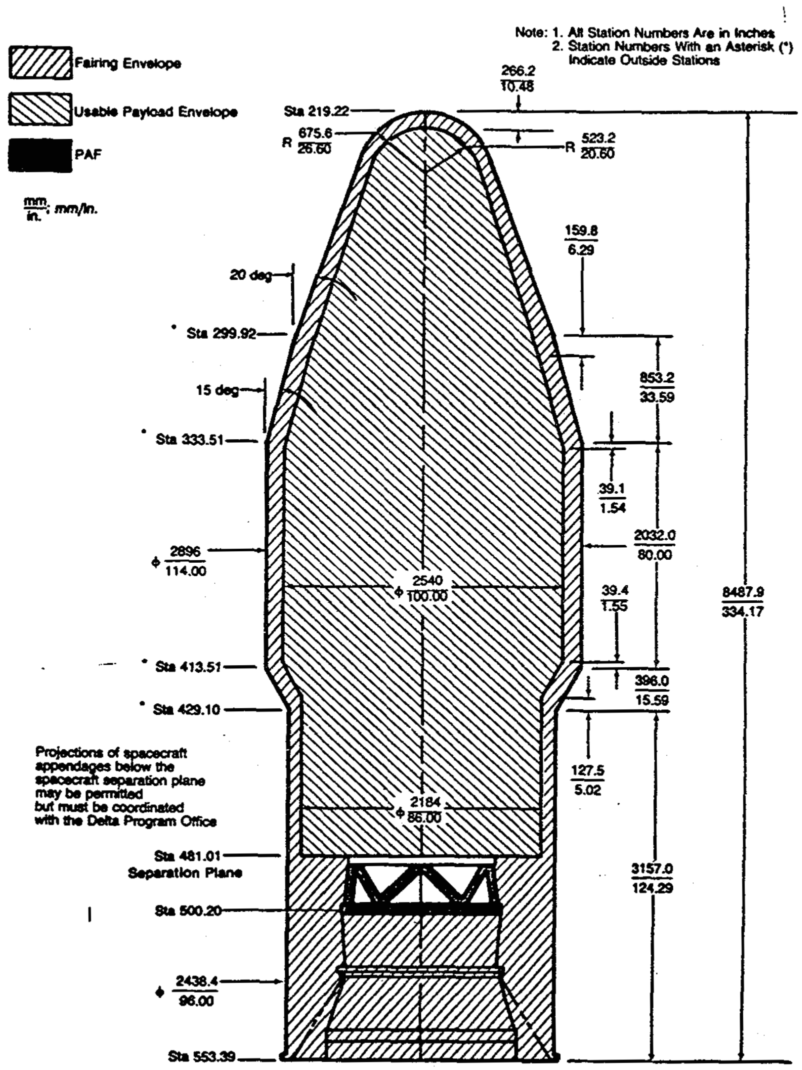
Delta II 792X Configurations

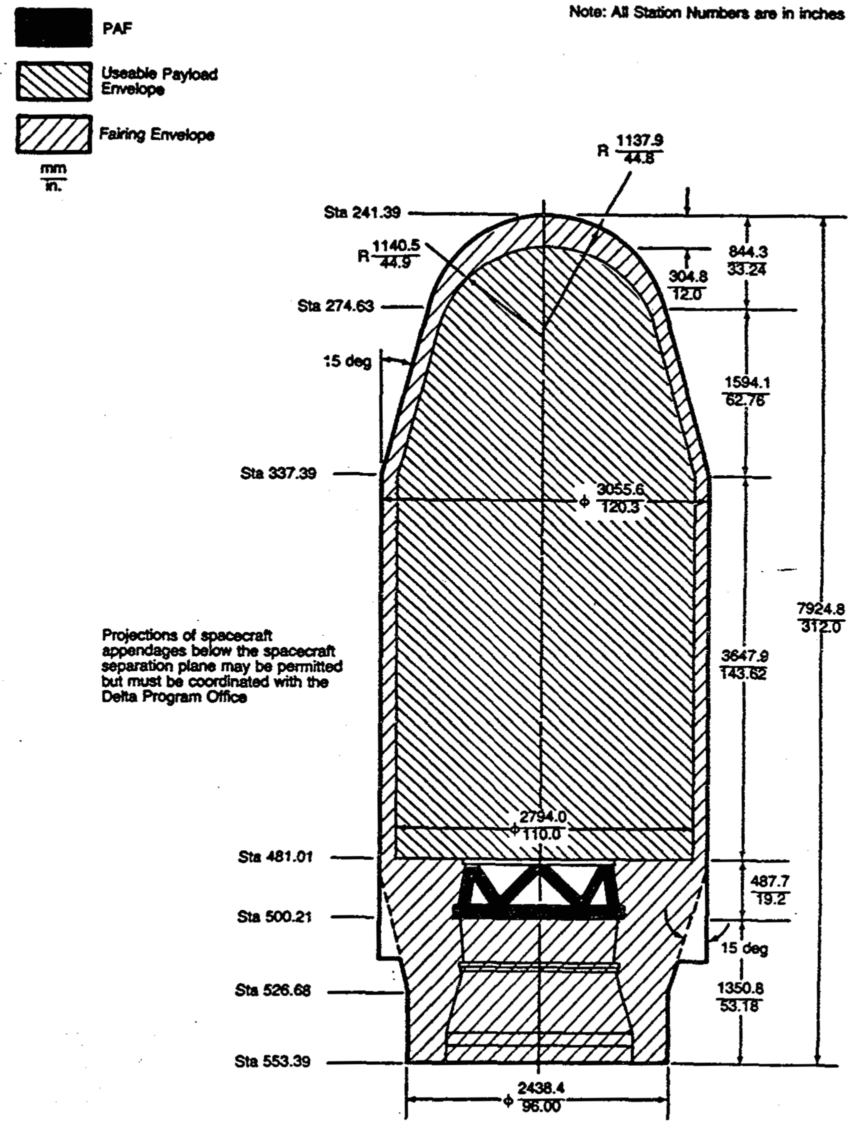




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Delta II Payload Fairings (PAFs)





Martin Marietta Titan II SLV Series

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Description of Titan II SLV Series derived from ex-ICBMs:

Two stage Titan II booster configuration using N2O4/Aerozine-50

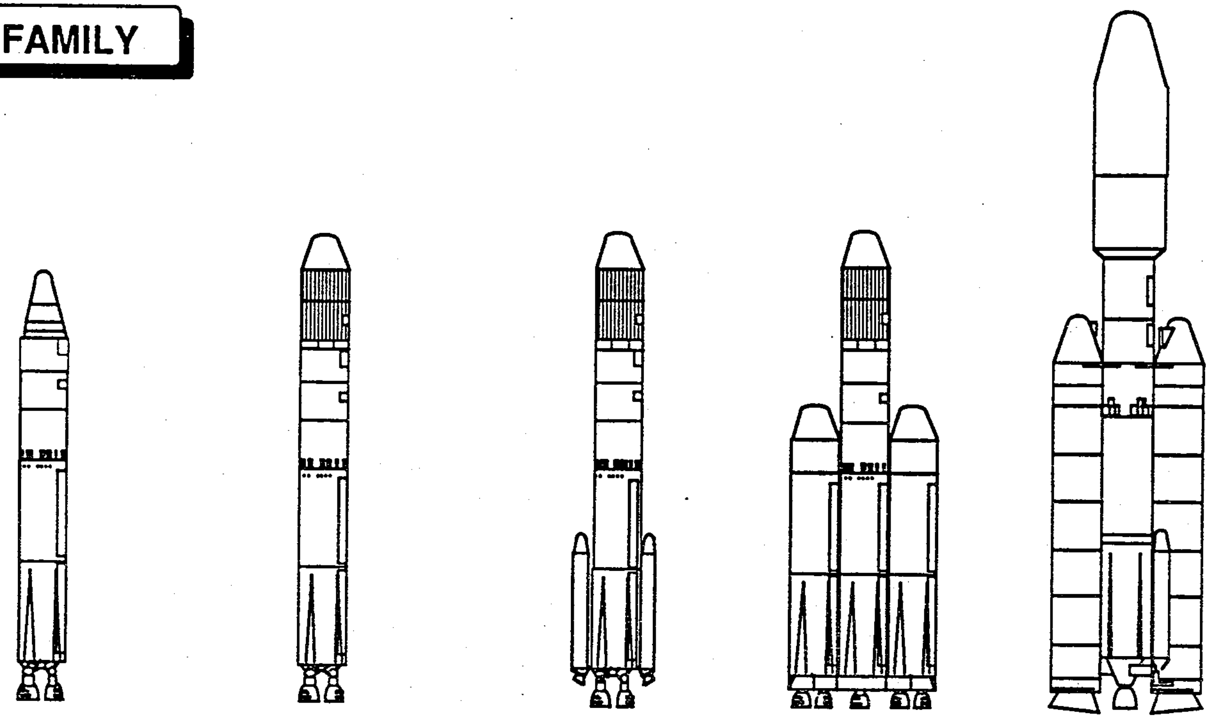
IIG	= No booster thrust augmentation, 3.0 meter Delta II PLF
IIS	= 2 to 10 strap-on Graphite Epoxy Motors (GEMs)
IIL	= Parallel configuration of two baseline boosters (1st stage only) attached to a baseline core (stages 1 & 2), 3.0 meter Delta II PLF
IIIL	= Parallel configuration of two baseline boosters (1st stage only) attached to a Titan III (Commercial Titan) core using Titan II stage 1 & 2 engines, 13.1' x 34' PLF (4.0 x 10.4 meter PLF)

Availability:

Number Remaining	41 (out of 55) unrefurbished, unmodified ICBMs
Expected Prod Run	Refurbish remainder of ICBM stock
	Plans to produce revisions of the Titan II series

Titan II Series Configurations

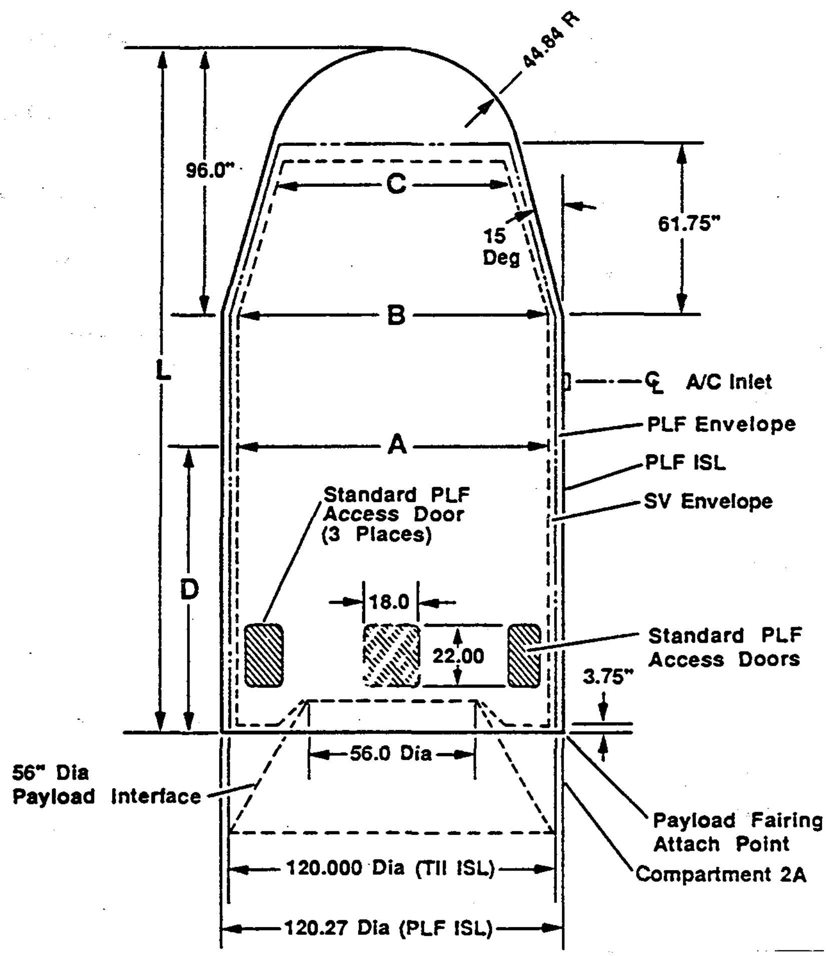
TITAN FAMILY



Basic	No Thrust Augmented	Solid Thrust Augmented	Liquid Thrust Augmented	Solid Thrust Augmented
4,200 lbs Polar	4,200 lbs Polar	7,800 lbs Polar	15,500 lbs Polar	24,000 lbs Polar
TII B	TII G	TII S	TII L/TIII L	TIII

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Titan II Payload Fairings (PAFs)



Dimension, In.						Weight Lb *
L,FT	L	A	B	C	D	
20	240	111.7	111.7	78.9	144	1435
25	300	111.6	111.1	77.9	144	1650
30	360	111.5	110.3	77.1	144	2000

* Weight Excludes Exterior Insulation, Acoustic Blankets and Standard Access Doors (Preliminary).

PAYLOAD FAIRING ENVELOPES

General Dynamics Altas Series

Description of Atlas Series ELVs:

LOX/RP-1 booster, one sustainer and two booster engines, 1.5 stage.

LOX/LH2 Centaur upper stage, two P&W RL-10 series engines, avionics.

Atlas II has longer tanks & more booster thrust. Atlas IIA has upgraded Centaur. Atlas IIAS has four Castor IVA solid rockets strapped to booster.

Availability:

Atlas I	1990	7 remaining (committed)
Atlas II	1991	
Atlas IIA	1991	
Atlas IIAS	1993	

Artemis

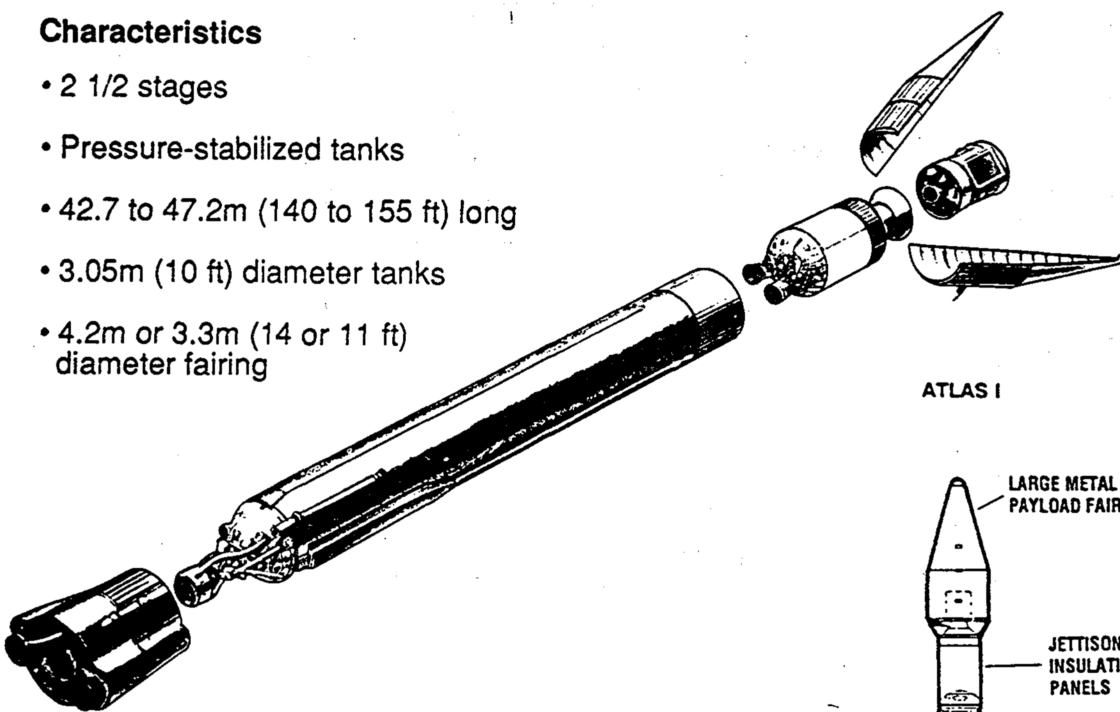
Atlas II Series Configurations

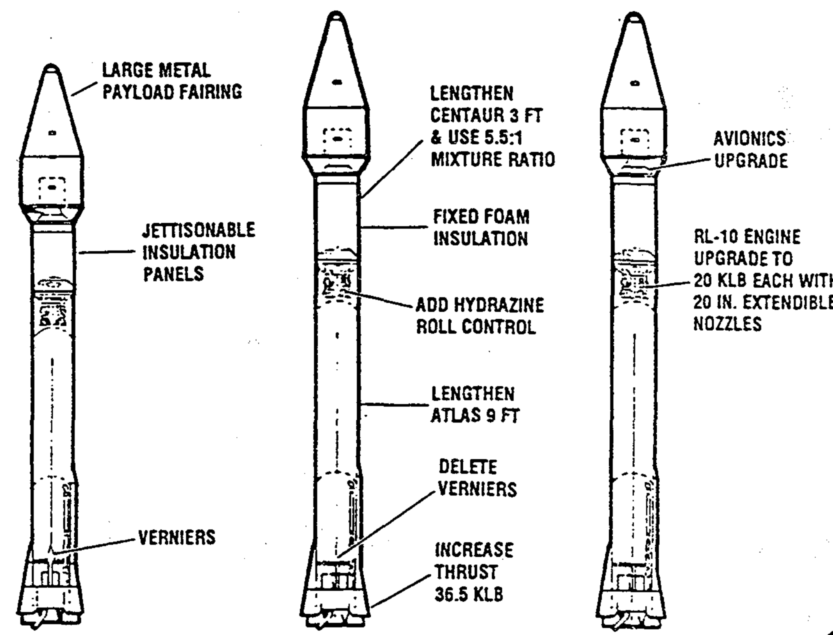
GENERAL DYNAMICS
Commercial Launch Services

ATLAS LAUNCH VEHICLE

Characteristics

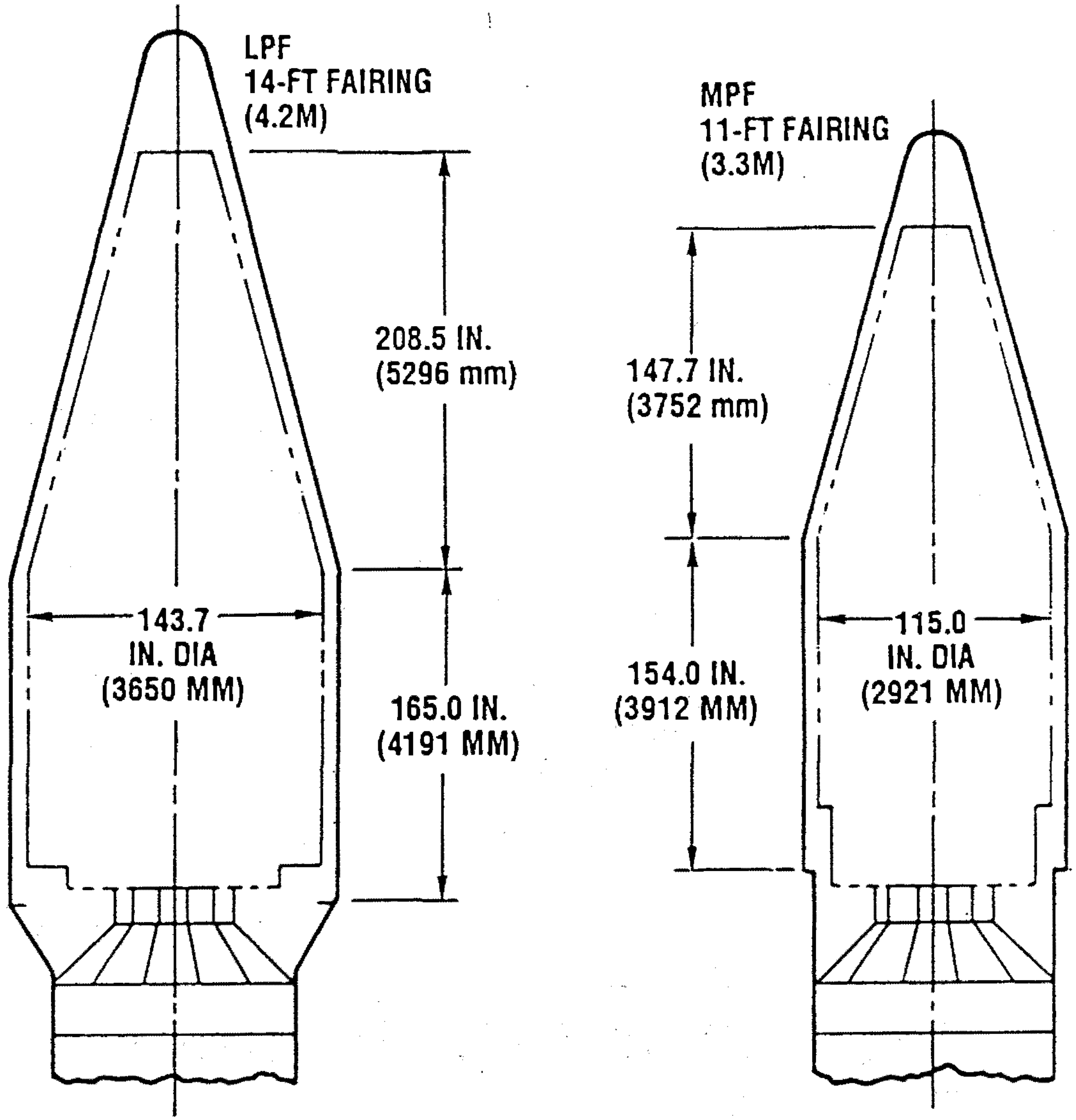
- 2 1/2 stages
- Pressure-stabilized tanks
- 42.7 to 47.2m (140 to 155 ft) long
- 3.05m (10 ft) diameter tanks
- 4.2m or 3.3m (14 or 11 ft) diameter fairing





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Atlas II Payload Fairings (PAFs)



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Payload Performance to LEO

PSW Performance (kg):	Delta II 7920	Titan IIS
185 km/28.7/ESMC	5,040*	5,430
Cost	$55 M	**$35 M

PSW Performance (kg):	Atlas II/IIA/IIAS	Titan IIL
185 km/28.5/ESMC	6,600/7,050/8,600***	9,060
Cost	$85/90/120 M	**$47 M

* 2.9m PLF ** W/O integration costs *** 4.2m (large) PLF

Artemis

Common Lunar Lander (CLL)

Conceptual Design
&
Mass Properties

Shelby Lawson, ET2, x36611 September 17, 1991

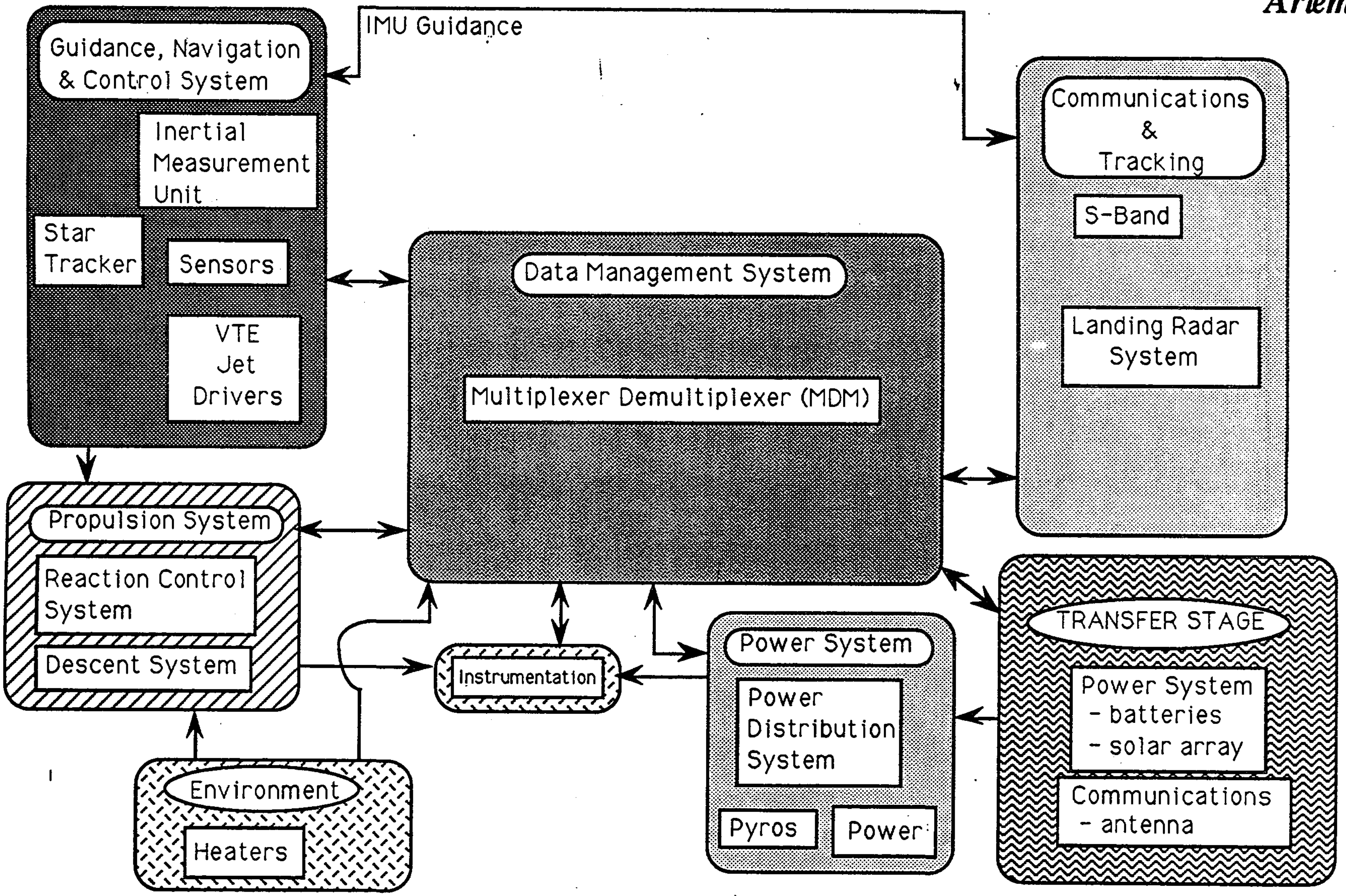
CLL Preliminary Conceptual Design

Artemis

- Lander sized to fit within Delta payload shroud
  - 3-lander legs stowed during flight
  - 5 S-band omni antennas
  - Landing radar underneath lander structure
  - 6 VTE bi-propellant engines for lunar descent and landing
  - 12 RCS engines for attitude control
- Crushable honeycomb legs deploy during lunar descent

  (dimensions are to be updated by George Sanger & Fred Abolfathi)
  - 4.0 meter footprint
  - 2.25 meter diameter lander base
- Transfer stage performs TLI, midcourse, LOI and lunar deorbit burns
  - 2 solar arrays and rechargeable batteries
  - 1 Transtar bi-propellant engine

CLL Schematic



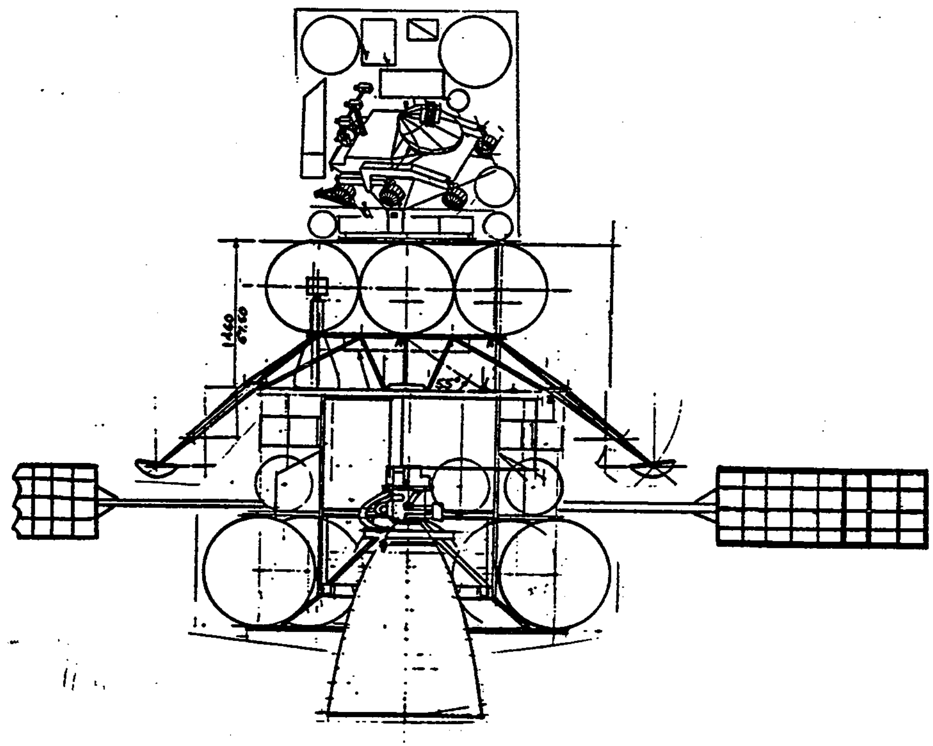
Shelby Lawson, ET2, x36611 September 17, 1991

NOTE: ALL MASS IS IN KILOGRAMS.

DESIGN MASS SUMMARY

Common Lunar Lander (CLL)

FUNCTIONAL SUBSYSTEM CODE	Lander	Transfer Stage		CLL Launch Adapter	
1.0 STRUCTURE	27	300		255	
2.0 PROTECTION	3				
3.0 PROPULSION	94	282			
4.0 POWER	39	93			
5.0 CONTROL	0	0			
6.0 AVIONICS	91	1			
7.0 ENVIRONMENT	2				
8.0 OTHER	24	4			
9.0 GROWTH	0				
DRY MASS	280	679		255	
10.0 NON-CARGO	11	104			
11.0 CARGO	200	0			
INERT MASS	491	784		255	
12.0 NON-PROPELLANT	0	0			
13.0 PROPELLANT	426	4,410			
GROSS MASS	917	5,193		255	



NOTE: ALL DIMENSIONS ARE IN METERS.

NOTE: Single string systems. Selective redundancy.
Lander: 5.8 m dia legs deployed, 2.75 m dia lander structure
Payload: 1.5 x 1.5 x 1.5 meter cube represented, 200 kg.

Adapter, Support Equipment:

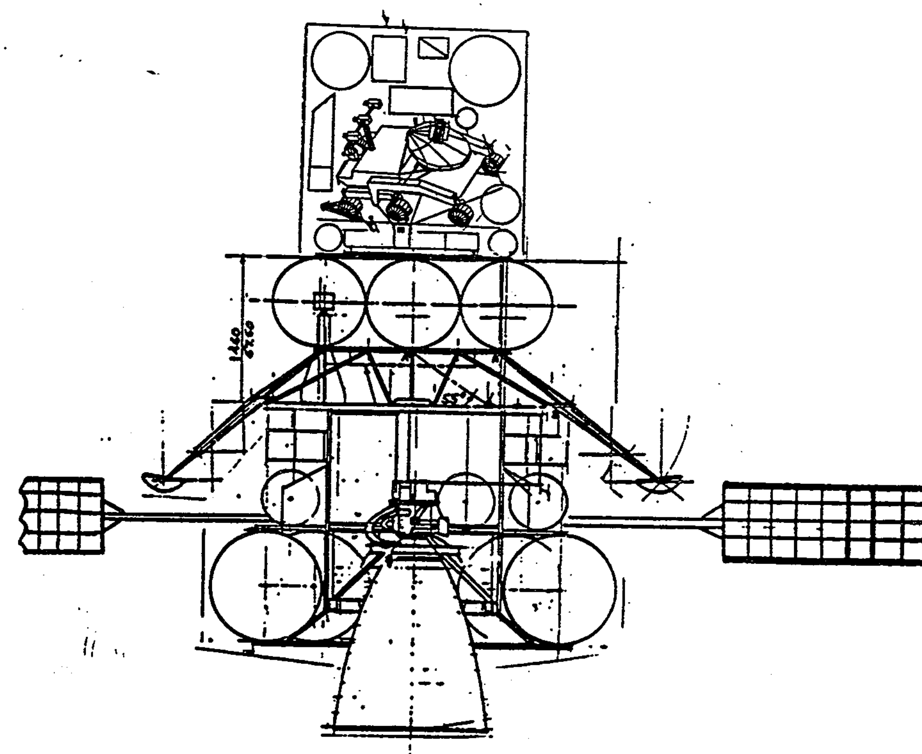
Launch mass = 6,365 kg

NOTE: ALL MASS IS IN KILOGRAMS.

DESIGN MASS SUMMARY

Common Lunar Lander (CLL)

FUNCTIONAL SUBSYSTEM CODE	Lander	Transfer Stage		CLL Launch Adapter	
1.0 STRUCTURE	27	300		270	
2.0 PROTECTION	3				
3.0 PROPULSION	96	291			
4.0 POWER	39	93			
5.0 CONTROL	0	0			
6.0 AVIONICS	91	1			
7.0 ENVIRONMENT	2				
8.0 OTHER	24	4			
9.0 GROWTH (15%)	42				
DRY MASS	325	689		270	
10.0 NON-CARGO	12	111			
11.0 CARGO	200	0			
INERT MASS	537	799		270	
12.0 NON-PROPELLANT	0	0			
13.0 PROPELLANT	465	4,671			
GROSS MASS	1,002	5,470		270	



NOTE: ALL DIMENSIONS ARE IN METERS.

NOTE: Single string systems. Selective redundancy.
Lander: 4.0 m dia legs deployed, 2.25 m dia lander structure
Payload: 1.5 x 1.5 x 0.6 meter Rover & instruments, 200 kg.
Transfer Stage: 87% Mass Fraction
Adapter, Support Equipment: 4% of CLL & Transfer Stage.

Launch mass = 6,742 kg

CLL Lander	Tl. Mass KG		Tl. Mass KG
1.0 Structure	27	**8.0 Other**	24
- Space Frame Assembly	19	- Landing System	22
- CLL / Transfer Stage Adapter	8	- Pyrotechnics	2
- Mounting Structure (info)	21	- Miscellaneous Mechanisms	0
2.0 Protection	3	**9.0 Growth**	42
- Insulation	3		
		CLL Lander Dry Mass	**325**
3.0 Propulsion	96		
- Integrated Propulsion System	96	**10.0 Non-Cargo**	12
		- Reserve and Residual Fluids	12
4.0 Power	39		
- Generation	13	**11.0 Cargo**	200
- Electrical Pwr Dist. & Control (EPDC)	16		
- Wiring	11		
		CLL Lander Inert Mass	**537**
6.0 Avionics	91		
- Guidance, Navigation & Control (GNC)	9	**12.0 Non-Propellant (Consummables)**	0
- Data Management System (DMS)	23		
- Instrumentation	6	**13.0 Propellant**	465
- Communications & Tracking (C&T)	53		
		CLL Lander Gross Mass	**1,002**
7.0 Environment	2		
- Environment Control System (ECS)	2		

CLL Transfer Stage	Tl. Mass KG
1.0 Structure	300
- Primary Body Structure	300
2.0 Protection	
- Insulation	
3.0 Propulsion	291
- Integrated Propulsion System	291
4.0 Power	93
- Generation	47
- Electrical Pwr Dist. & Control (EPDC)	27
- Wiring	18
6.0 Avionics	1
- Instrumentation	1
7.0 Environment	
- Environment Control System (ECS)	

	Tl. Mass KG
8.0 Other	4
- Miscellaneous Mechanisms	4
9.0 Growth	0
CLL Transfer Stage Dry Mass	689
10.0 Non-Cargo	111
- Reserve and Residual Fluids	111
11.0 Cargo	0
CLL Transfer Stage Inert Mass	799
12.0 Non-Propellant (Consummables)	0
13.0 Propellant	4,671
CLL Transfer Stage Gross Mass	5,470

Launch Adapter & Support	270	Used on launch from ELV. Estimate.

Total Launch Mass	6,742

CLL: LANDER SUBSYSTEM:	Tl. Mass (KG)	No	Comments
1.0 Structure:	**27.2**		Contact George Sanger or Fred Abolfathi, LESC, 333-7254.
Space Frame Assembly	19.2		
CLL / Transfer Stage Adapter	8.0		
Subsystem Mounting (info only)	20.8		

CLL: LANDER SUBSYSTEM:	Tl. Mass (KG)	No	Comments
2.0 Protection:	**3.0**		Contact Steve Bailey, 283-5411. Estimated.
Insulation	3.0		

CLL: LANDER SUBSYSTEM:	Tl. Mass (KG)		No	Comments
3.0 Propulsion:	96.0			Contact Don Hyatt, x39019. Performs descent & landing burns.
Integrated Propulsion System	96.0			Bipropellant RCS and Primary Engine System, Delta V=1820 m/s.
Fuel Tanks		7.2	2	Spherical, 59 cm dia.
Oxidizer Tanks		7.2	2	Spherical, 59 cm dia.
Pressurant Tanks		12.3	4	Spherical, 30 cm dia.
RCS Engines		12.6	12	Marquardt R-6C
Descent Lander Engines		46.3	6	TRW VTE engines, Isp=300 sec.
Lines, Valves & Insulation		8.7		Historical estimate.
Mounting Structure		1.7		Historical estimate.

CLL: LANDER SUBSYSTEM:	Tl. Mass (KG)		No	Comments
4.0 Power:	39.3			Contact Betsy Kluksdahl, x36484.
Generation	13.1			
Primary Batteries		11.3		
Mounting Structure		1.8		Structure factor of 15.6% supplied by George Sanger, 333-7254.
Electrical Pwr Dist. & Control (EPDC)	15.7			Contact Betsy Kluksdahl, x36484. Preliminary estimate.
Bus Controller		13.6	1	38.1x38.1x15.2 cm
Mounting Structure		2.1		Structure factor of 15.6% supplied by George Sanger, 333-7254.
Wiring	10.5			Contact Betsy Kluksdahl, x36484. Estimate based on ACRV
Cable		9.1		Includes connectors, 25.9K cm3
Mounting Structure		1.4		Structure factor of 15.6% supplied by George Sanger, 333-7254.

CLL: LANDER SUBSYSTEM:	Tl. Mass (KG)		No	Comments
6.0 Avionics:	91.2			
Guidance, Navigation and Control (GNC)	9.2			Contact Nancy Smith, x38275. Features integrated DMS system.
Inertial Measurement Unit (IMU)		7.3	1	Honeywell-764. 17.7x17.7x22.9 cm, 7200 cm3, 40W.
Star Tracker		1.0	1	Lawrence Livermore. 18x18x25 cm, 8100 cm3, 8W.
Mounting Structure		0.9		Structure factor of 10.8% supplied by George Sanger, 333-7254.
Data Management System (DMS)	22.9			Contact Nancy Smith, x38275.
Multiplexer/DeMultiplexer (MDM)		20.0	1	Honeywell, similar to SSF, contains RJD functions. 37xc23x34 cm, 29K cm3, 100W.
Mounting Structure		2.9		Structure factor of 14.5% supplied by George Sanger, 333-7254.
Instrumentation	5.8			Contact S. Lawson, x36611. Based on historical data. Dist. among subsystems.
Sensors		3.5		
Signal Conditioners		1.5		
Mounting Structure		0.8		Structure factor of 16.6% supplied by George Sanger, 333-7254.
Communications & Tracking (C&T)	53.3			Contact Henry Chen, x30128, Zafar Taqvi, 333-6544. 8/16/91.
• S-Band System	23.9			Uses DSN 34 subnet, for telemetry, ranging and command.
Transponder		3.3	1	Motorola, Inc. Cmd detector. 16x20x11 cm, 3500 cm3, 8W avg, 17.5W peak.
RF Assembly		7.4	1	New, 16x20x3224 cm, 7800 cm3, 18.8W avg., 71W peak.
Processing Module		3.0	1	New; process, signal condition, control and monitors. 16x20x15 cm, 4800 cm3, 27W.
Antenna		4.6	5	TRW, Log conical spiral. 12.5 cm dia x 30 cm h, 3300 cm3, 0W.
Coaxial Cable		2.4	1	Gore, 900 cm3, dependent on communication equipment placement.
Mounting Structure		3.2		Structure factor of 15.6% supplied by George Sanger, 333-7254.
• Tracking	29.4			Contact Bill Culpepper, x31479. Viking Heritage, Teledyne Ryan Co.
Landing Radar		22.1	1	Antenna on surface, 76.2x76.2x8.26 cm, 68W
Altimeter		5.1	1	23.4x14.7x20.1 cm, 28.5W
Altimeter Antenna		0.7	1	Cone shaped, 1721 cm3
Coax cable		0.1		Connection between altimeter and antenna. Estimate.
Mounting Structure		1.4		Structure factor of 5.0% supplied by George Sanger, 333-7254.

CLL: LANDER SUBSYSTEM:	Tl. Mass (KG)		No	Comments
7.0 Environment:	**2.1**			
Environment Control System (ECS)	2.1			Contact Steve Bailey, 283-5411. Estimated.
Heaters		2.0		Estimate. Used to keep engines, tanks and subsystems warm.
Mounting Structure		0.1		Structure factor of 5.6% supplied by George Sanger, 333-7254.

CLL: LANDER SUBSYSTEM:	Tl. Mass (KG)		No	Comments
8.0 Other:	**23.7**			
Landing System	21.9			Contact George Sanger, LESC, 333-7254.
Lander Legs		18.0	3	Alum. honeycomb.
Mounting Structure		3.9		Structure factor of 21.6% supplied by George Sanger, 333-7254.
Pyrotechnics System	1.8			Contact Betsy Kluksdahl, x36484.
N/C Pyrovalve		0.6	4	RCS Isolate, Unidynamics (P/N 51-1630) 8x5x5 cm, 200 cm3, 5A @ 30 mSec peak pwr.
Uplock Cutter		0.8	3	Lander Leg deploy,Apollo,16x12x5 cm,960 cm3,5A @ 30 mSec peak pwr.
Mounting Structure		0.5		Structure factor of 38.5% supplied by George Sanger, 333-7254.

CLL: LANDER SUBSYSTEM:	Tl. Mass (KG)	No	Comments
9.0 Growth:	42.4		15% of all subsystems.

CLL Lander DRY MASS	325

CLL: LANDER SUBSYSTEM:	Tl. Mass (KG)	No	Comments
10.0 Non-Cargo	**12.0**		
Reserve and Residual Fluids	12.0		
IPS Fuel Reserves	0.0		0% reserves, D. Hyatt.
IPS Fuel Residuals	3.6	2	2% residuals, Monomethylhydrazine (MMH), Contact D. Hyatt.
IPS Oxidizer Reserves	0.0		0% reserves, D. Hyatt.
IPS Oxidizer Residuals	5.9	2	2% residuals, Nitrogen Tetroxide (NTO), Contact D. Hyatt.
IPS Pressurant	2.5	4	Helium, D. Hyatt.

CLL: LANDER SUBSYSTEM:	Tl. Mass (KG)	No	Comments
11.0 Cargo	**200.0**		Contact Alan Binder, 283-5849.
Scientic Payloads	200.0		
Rover + Instruments	200.0	1	150 kg rover + 50 kg instruments; 1.5x1.5x1.5 m box dimensions assume

CLL Lander INERT MASS	537

CLL: LANDER SUBSYSTEM:	Tl. Mass (KG)	No	Comments
12.0 Non-Propellant (Consummables)	0.0		

CLL: LANDER SUBSYSTEM:	Tl. Mass (KG)	No	Comments
13.0 Propellant	**465.1**		Delta V = 1820 m/s
Fuel	176.2	2	Monomethylhydrazine (MMH)
Oxidizer	288.9	2	Nitrogen Tetroxide (NTO)

CLL Lander GROSS MASS	**1,002**	

CLL: TRANSFER STAGE SUBSYSTEM:	Tl. Mass (KG)	No	Comments
1.0 Structure:	**300.0**		Contact Steve Bailey, 283-5411. Assume 5% of t.s. gross mass.
Primary Body Structure	300.0		Includes all subsystem mass except power & mechanisms.

CLL: TRANSFER STAGE SUBSYSTEM:	Tl. Mass (KG)	No	Comments
2.0 Protection:	**0.0**		Contact Steve Bailey, 283-5411.
Insulation	0.0		Included in structure mass.

CLL: TRANSFER STAGE SUBSYSTEM:	Tl. Mass (KG)	No	Comments
3.0 Propulsion:	**291.4**		Contact Don Hyatt, x39019. Performs RCS, TLI, LOI & deorbit burns
Integrated Propulsion System	291.4		Bipropellant RCS and Primary Engine System, Delta V=4100 m/s.
Fuel Tanks	40.1	4	Spherical, 99 cm dia.
Oxidizer Tanks	42.8	4	Spherical, 102 cm dia.
Pressurant Tanks	77.0	4	Spherical, 55 cm dia.
RCS Engines	26.8	12	Marquardt R-IE, 25 lbs thrust
Transfer Stage Engine	66.7	1	Transtar engine, Isp=328 sec.
Lines, Valves & Insulation	31.6		Historical estimate.
Mounting Structure	6.3		Historical estimate.

CLL: TRANSFER STAGE SUBSYSTEM:	Tl. Mass (KG)	No	Comments
4.0 Power:	92.6		Contact Betsy Kluksdahl, x36484.
Generation	47.3		
Rechargeable Batteries	11.3		Silver-Zinc chemistry (Zn-AgO), 3 modules,0.01 M3, jettison prior to deorbit
Solar Arrays	36.0	2	Silicon cells, accordian-style, 1.33 w x 4.0 h m ea.
Mounting Structure	0.0		Included in structure mass.
Electrical Pwr Dist. & Control (EPDC)	27.2		Contact Betsy Kluksdahl, x36484. Preliminary estimate.
Solar Array Controller	9.1	1	25.4x38.1x15.2 cm
Battery Charger	9.1	1	25.4x30.5x12.7 cm
Bus Controller	9.1	1	38.1x38.1x15.2 cm
Mounting Structure	0.0		Included in structure mass.
Wiring	18.1		Contact Betsy Kluksdahl, x36484. Estimate based on ACRV
Cable	18.1		Includes connectors, 25.9K cm3
Mounting Structure	0.0		Included in structure mass.

CLL: TRANSFER STAGE SUBSYSTEM:	Tl. Mass (KG)	No	Comments
6.0 Avionics:	1.0		
Communications	1.0		
Antenna	1.0	1	TRW, Log conical spiral. 12.5 cm dia x 30 cm h, 3300 cm3, 0W.
Mounting Structure	0.0		Included in structure estimate

CLL: TRANSFER STAGE SUBSYSTEM:	Tl. Mass (KG)	No	Comments
7.0 Environment:	0.0		Contact Steve Bailey, 283-5411. Included in structure estimate.

CLL: TRANSFER STAGE SUBSYSTEM:	Tl. Mass (KG)	No	Comments
8.0 Other:	3.6		
Mechanisms	3.6		Contact George Sanger, 333-7254.
Solar Array Deployment & Tracking	3.6	2	
Mounting Structure	0.0		Included in structure mass.

CLL: TRANSFER STAGE SUBSYSTEM:	Tl. Mass (KG)	No	Comments
9.0 Growth:	0.0		No growth or contingency mass calculated. Using mass fraction.

CLL Transfer Stage DRY MASS	689	

CLL: TRANSFER STAGE SUBSYSTEM:	Tl. Mass (KG)	No	Comments
10.0 Non-Cargo	110.7		
Reserve and Residual Fluids	110.7		
IPS Fuel Reserves	0.0		0% reserves, D. Hyatt.
IPS Fuel Residuals	34.1	4	2% residuals, Monomethylhydrazine (MMH), Contact D. Hyatt.
IPS Oxidizer Reserves	0.0		0% reserves, D. Hyatt.
IPS Oxidizer Residuals	61.3	4	2% residuals, Nitrogen Tetroxide (NTO), Contact D. Hyatt.
IPS Pressurant	15.4	4	Helium, D. Hyatt.

CLL: TRANSFER STAGE SUBSYSTEM:	Tl. Mass (KG)	No	Comments
11.0 Cargo	0.0		

CLL Transfer Stage INERT MASS	**799**	

CLL: TRANSFER STAGE SUBSYSTEM:	Tl. Mass (KG)	No	Comments
12.0 Non-Propellant (Consummables)	0.0		

CLL: TRANSFER STAGE SUBSYSTEM:	Tl. Mass (KG)	No	Comments
13.0 Propellant	4,671.1		3200 m/s TLI, 30 m/s midcourse, 840 m/s LOI, 30 m/s deorbit
Fuel	1,668.3	4	Monomethylhydrazine (MMH)
Oxidizer	3,002.9	4	Nitrogen Tetroxide (NTO)

CLL Transfer Stage GROSS MASS	**5,470**	

CLL: Launch Adapter & Support Equipment

SUBSYSTEM:	Tl. Mass (KG)	No	Comments Contact Steve Bailey, 283-5411.
1.0 Structure	269.7		Includes ground support equipment, cables, pyros.
8.0 Other	0.0		
9.0 Growth	0.0		Included in structure.

Launch Adapter & Support	270	1	Used on launch from ELV.

CLL Mission Mass Summary	Tl. Mass (KG)	Comments
Launch Mass	6742	CLL Gross Mass + Transfer Stage Gross Mass + Launch Adapter Gross Mas
Prior to leaving Earth Orbit	6472	Launch Mass - Launch Adapter
5 day Moon trip	?	Prior to leaving Earth Orbit - TLI burn propellant
14 day Lunar orbit wait	?	5 day moon trip - LOI burn propellant
Lunar deorbit	?	14 day lunar orbit wait - Deorbit burn propellant
Prior to descent burn	1002	Lunar deorbit - Transfer Stage Inert Mass
Landed Vehicle	537	Prior to descent burn - Descent burn propellant
Scientific Payload	200	Landed Vehicle - CLL Inert Mass + Payload

Other Design Information	Tl Mass-kg	
CLL Payload	200	
CLL Structure	27	Primary
CLL Subsystems	202	Without dry propulsion system.
Transfer Stage Structure	300	Primary, Secondary and Mounting Structure
Transfer Stage Subsystems	97	Without dry propulsion system.
Transfer Stage "Payload"	1002	CLL Gross Mass

Structure and Mechanics

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Primary Structure

Space Frame Assembly	19 kg	
CLL / Transfer Stage Adapter Ring	8 kg	
Lander Legs	22 kg	
Mounting Structure	21 kg	Total = 70 kg

Structure Factor = 70 kg / 917 kg = .076

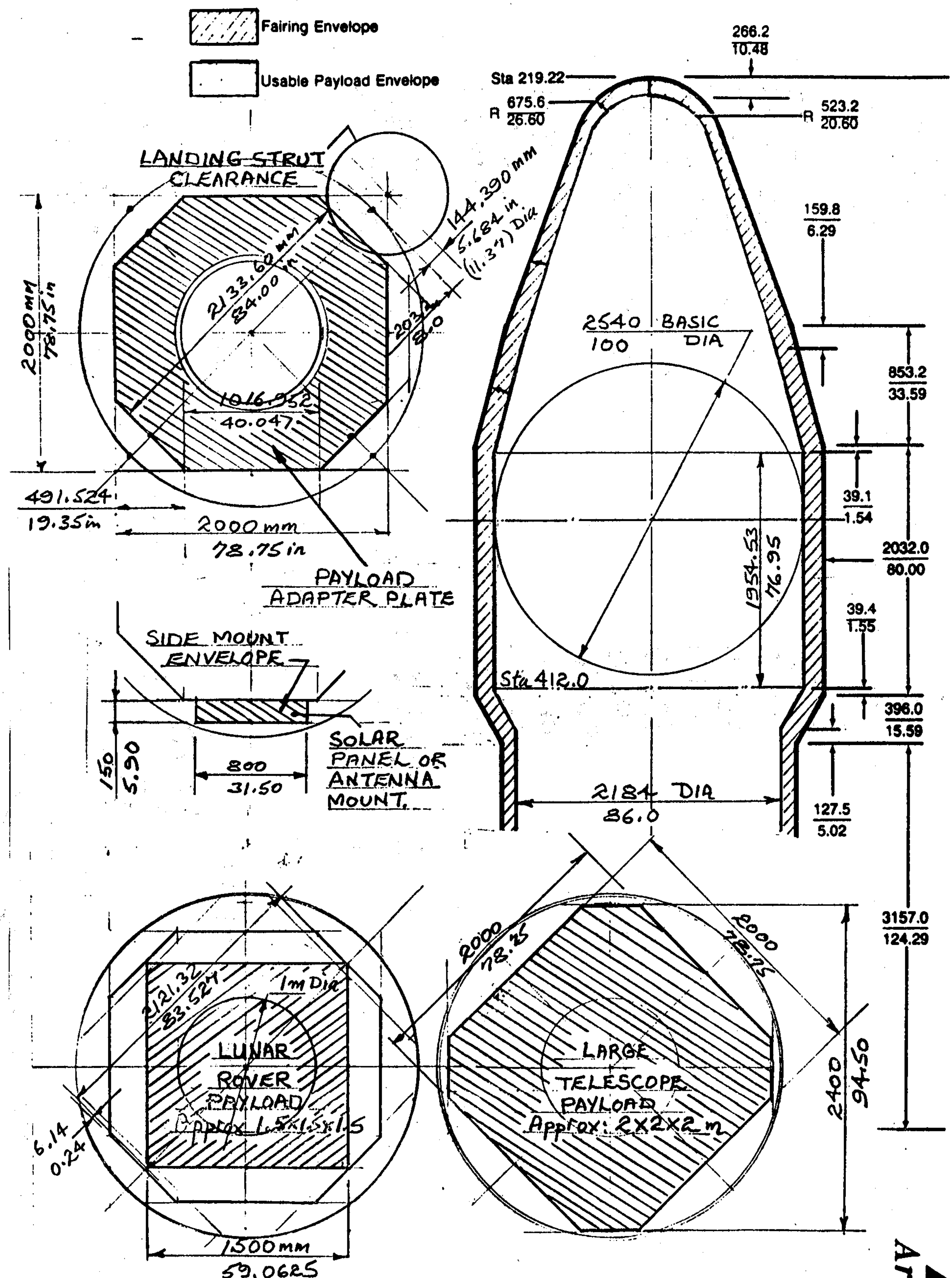
Secondary Structure

Mounting Structure	Structure Factor
Propulsion	0.185
Power	0.156
GNC	0.108
DMS	0.145
Instrumentation	0.166
Communications	0.156
Tracking	0.050
Active Thermal	0.056
Landing Legs	0.216
Pyros	0.385

- The mounting structure masses are incorporated in the design mass statement.

George Sanger/LESC/333-7254
Lockheed Engineering & Sciences Company

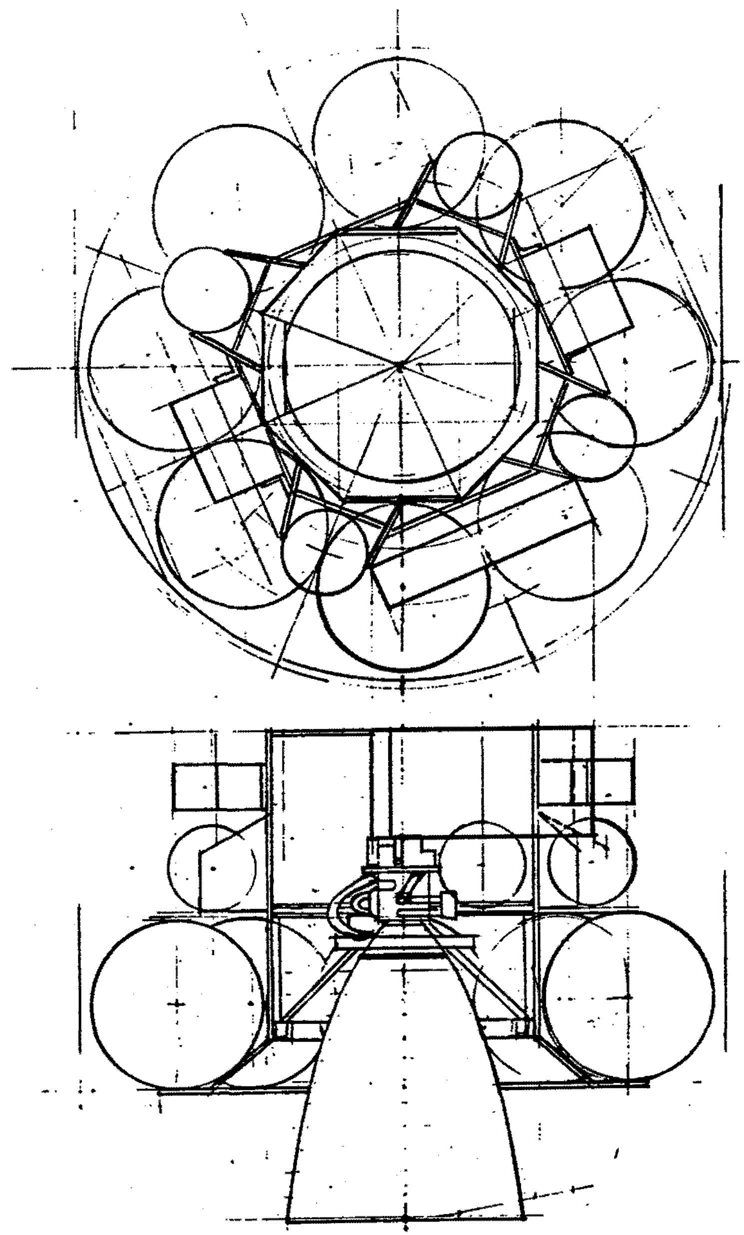
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CLL DELTA GEOMETRY

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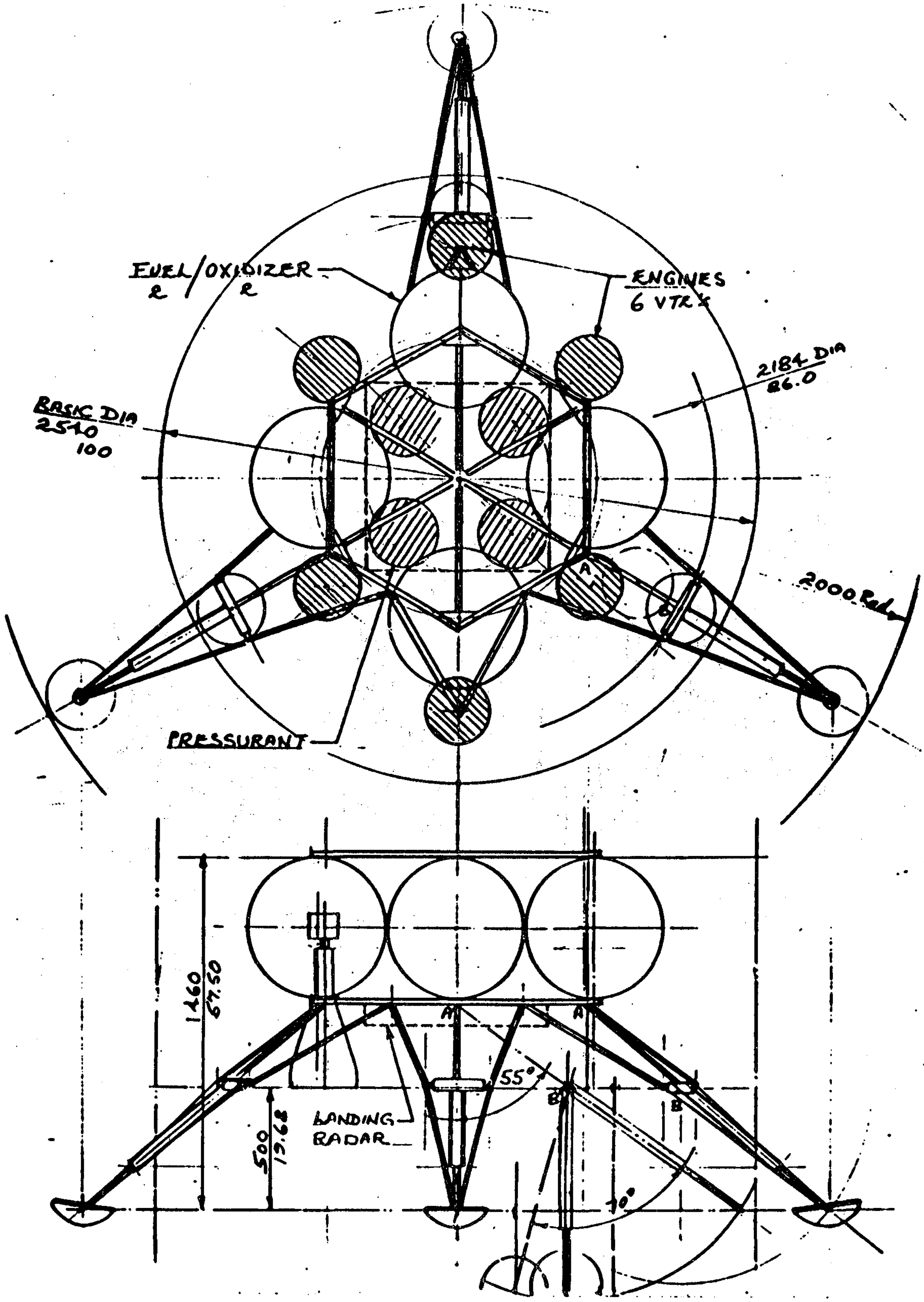


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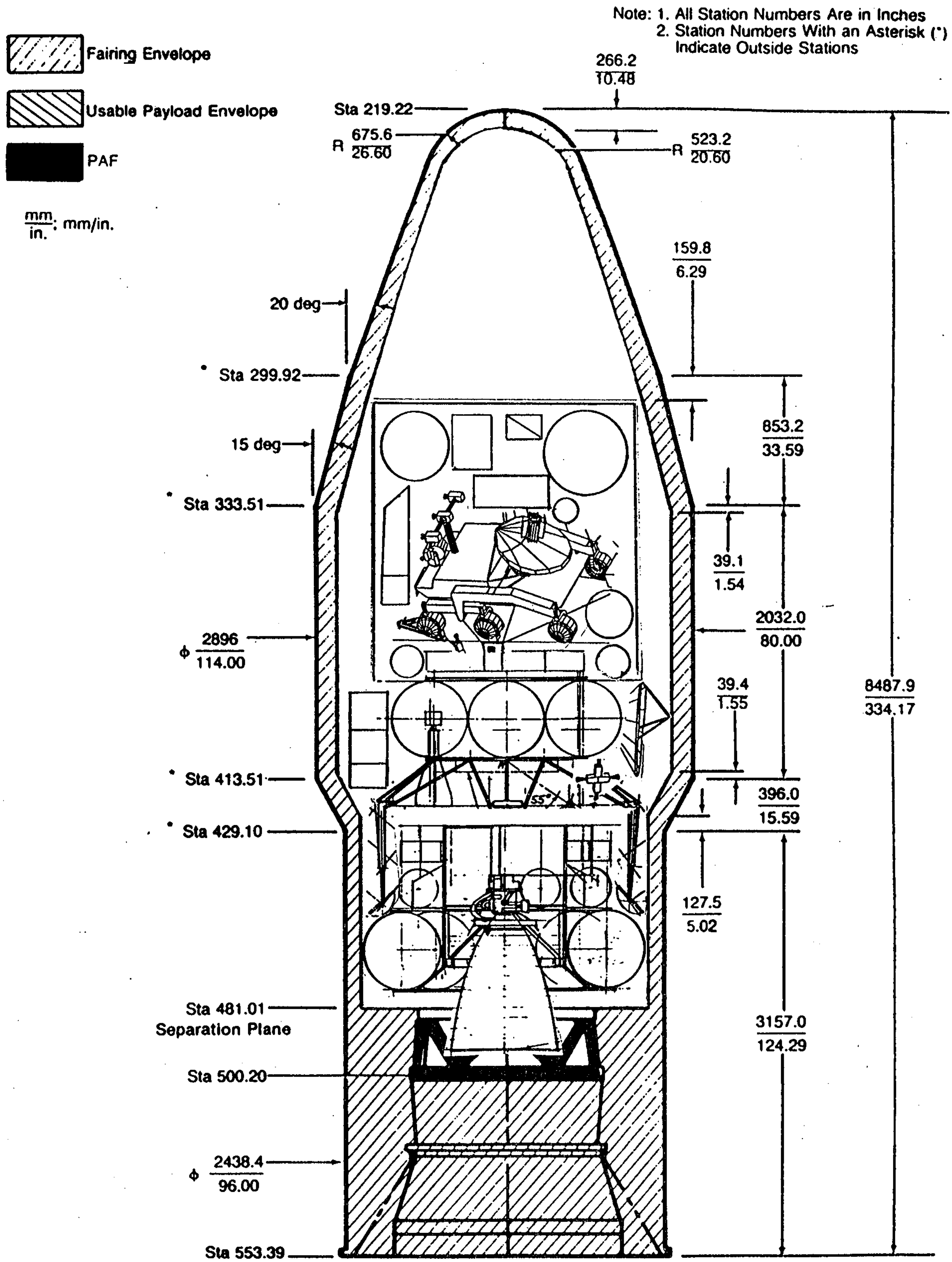
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Jonette Stecklein/ET2/x36624

Systems Engineering Division

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Common Lunar Lander Propulsion System

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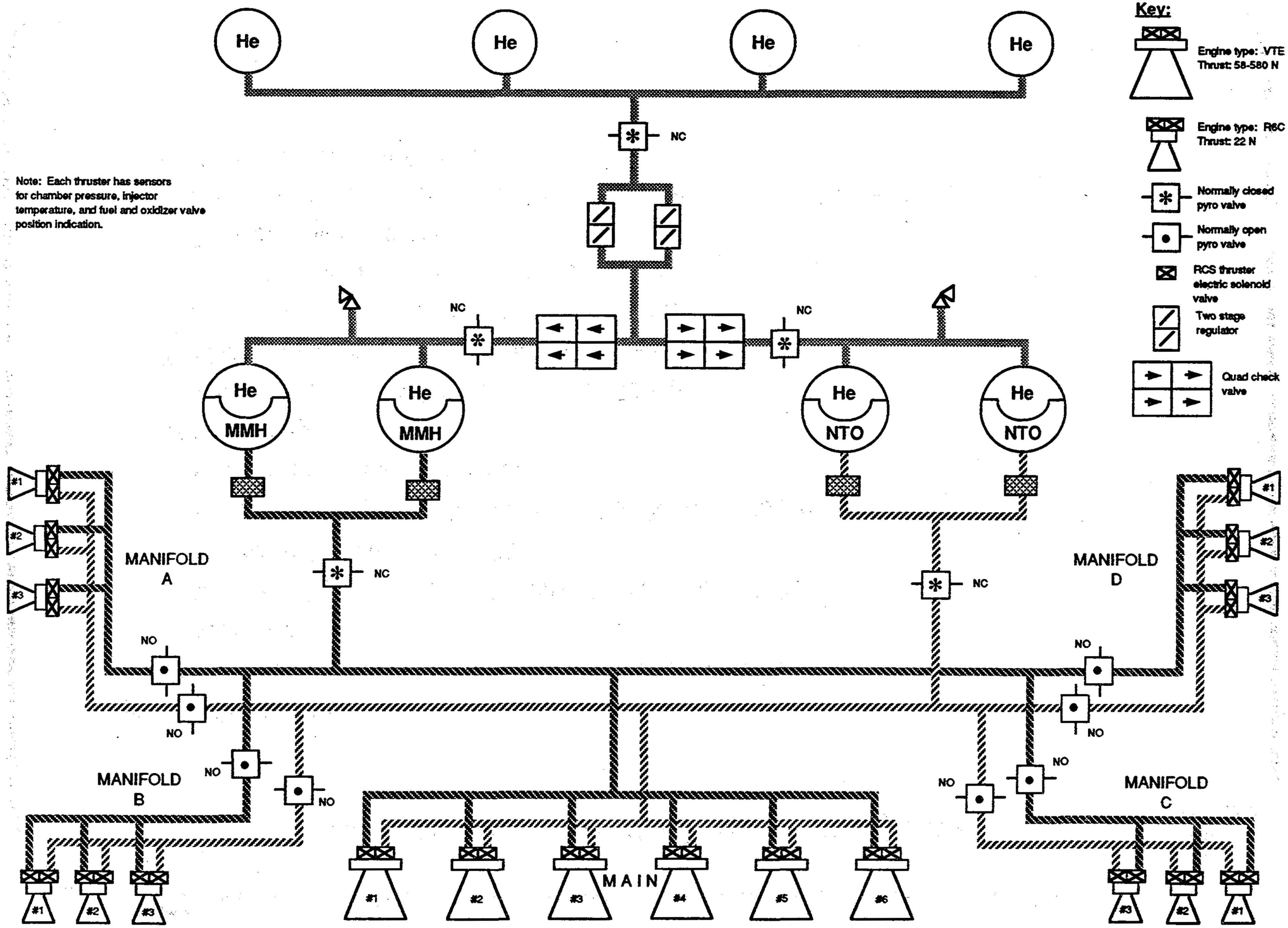
System Characteristics

- Two-stage pressure-fed storable bipropellant (MMH/NTO)
- Lander stage
  - Six main engines - TRW Variable Thrust Engines (VTE)
    - Originally baselined for OMV
    - 10:1 throttling capability from 58 - 580 N (13 - 130 lbf)
    - Throttling required for landing
- Transfer stage
  - Aerojet Transtar engine - 16731 N (3750 lbf)
- Twelve attitude control engines for each stage
  - Marquardt R6-C's (lander) and R-1E's (transfer)
    - 22 N (5 lbf) and 110 N (25 lbf) respectively
  - Extensive flight history
  - Arranged in quads: two 4-engine clusters and two 2-engine clusters
  - Provide 3-axis stabilization

Don Hyatt/EP4/x39019

COMMON LUNAR LANDER PROPULSION SYSTEM

9/12/91 RJS



Note: Each thruster has sensors for chamber pressure, injector temperature, and fuel and oxidizer valve position indication.

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Common Lunar Lander Propulsion System

Point Design Output

- Dry propulsion system mass breakdown:

	Lander Stage	Transfer Stage
- Fuel tanks	6.7 kg	38.6 kg
- Oxidizer tanks	6.7	41.0
- Pressurant tanks	11.3	72.7
- Engines (includes controllers)	58.8	93.4
- Lines/Valves/Thermal	8.4	30.1
- Mounting hardware	1.7	6.0
- Pressurant	2.2	4.5
- Residual fuel	3.3	32.2
- Residual oxidizer	5.4	57.9
Total dry system mass	104.5 kg	386.4 kg

- Wet propulsion system includes above plus usable propellant

	Lander Stage	Transfer Stage
- Usable fuel	161.2 kg	1574.9 kg
- Usable oxidizer	264.4	2834.8
Total usable propellant	425.6 kg	4409.7 kg
Total wet propulsion system mass	530.1 kg	4796.1 kg

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Common Lunar Lander Propulsion System

System Mission Requirements

- Provide propulsive maneuvers and attitude control from LEO through landing
  - TLI: 3200 m/sec
  - MCC's: 30 m/sec
  - LOI: 840 m/sec
  - D/O: 30 m/sec
  - TD&L: 1820 m/sec

Key Drivers to Subsystem Selection

- Multiple restart ==> liquid propellants
- Simplicity, orbital stay time, packaging ==> storable propellants
- Landing ==> throttling engines

System Readiness Level

- All elements are flight proven except:
  - VTE : Complete development program then proceed into qualification
  - Transtar: Flight weight engine developed, ready for qualification
  - Tanks: Custom sized for propellant/pressurant load, industry survey required

Avionics Subsystem

Subsystem Requirements:

- Guidance , navigation and control of the spacecraft
- Central computer for all subsystems
- Data storage for all subsystems for telemetry purposes

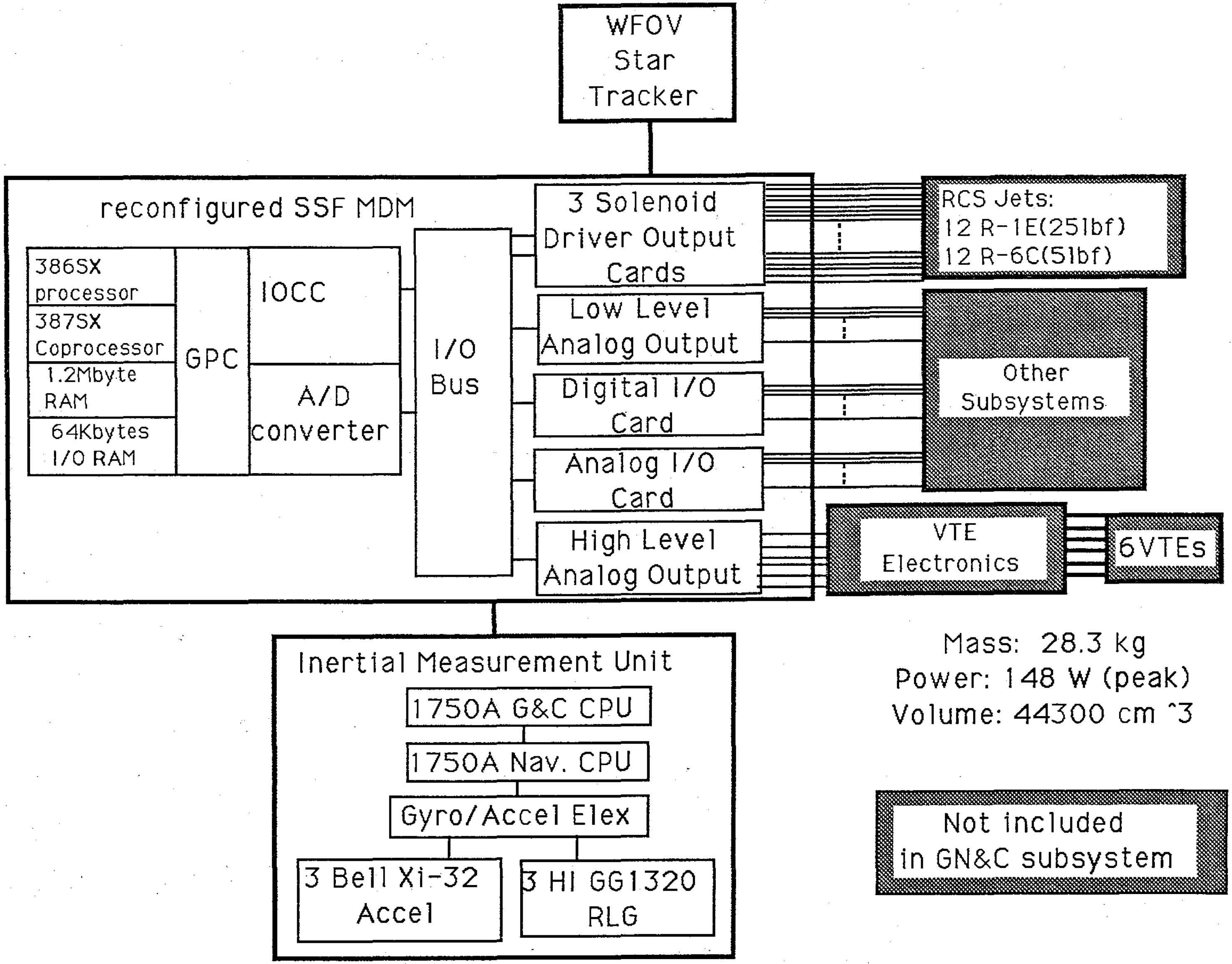
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Avionics Subsystem

Unit	Cost $	Mass kg	Vol. cm^3	Size cm	Power W	#	Description	Rqmts
IMU	275K/1 (TBD NRE : nav. algorithm)	7.3	7200	17.7x 17.7x 22.9	40	1	• Honeywell H-764 • available 92 • 3 RLGs, 3 accel. • 2 CPUs • MTBF > 4000 hrs • Contact: L. Brown (813) 539-5814	• alignment every 12 hrs & prior to major burns
Star Tracker	500K/1 3M/10 (TBD NRE : quaternion algorithm & processor)	1	8100	18x 18x 25	8	1	• Lawrence Livermore • Space Cert. in 92 • available 1/93 • converts 28V to ± 5, ± 15 V • contact: I. Lewis (415)294-6531	• access to stars • cold plate
GPC	inc.	inc.	inc.	inc.	inc.		• in MDM	n/a
Data Mem.	inc.	inc.	inc.	inc.	inc.		• in MDM	n/a
MDM	450K/1 (< 600K NRE: 28V power supply)	20	29000	37x 23x 34	50 (nom) 100 (peak)	1	• Honeywell Space Station MDM • available 2 Qtr 92 • interfaces for all subsystems • reconfigured by changing cards • programming, debugging & hardware integration testing with workstations • contact: L. Brown (813) 539-5814	• access to all systems by cable • cold plate, passively cooled
RCS RJD	inc.	inc.	inc.	inc.	inc.	3	• Solenoid Driver output card in MDM	
Avionics	1.225M/1 10.25M/10	28.3	44300		98 nom 148 pk			

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Avionics Subsystem



Mass: 28.3 kg
Power: 148 W (peak)
Volume: 44300 cm ^3

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Avionics Subsystem

Trade Studies Performed:

- IMU
- Star Tracker vs. Horizon Sensor & Sun Sensor
- RJDs vs Solenoid Driver Cards
- MDM vs GPC, Data Storage & Standard Bus

Programs Studied:

- ACRV
- AFE
- Apollo
- Lifesat
- MRSR
- OMV
- Shuttle
- Surveyor
- Viking

Companies & Agencies Contacted:

- Ball Aerospace
- Bell Lab
- Bendix
- Draper Lab
- Delco Systems
- Gulton
- Honeywell
- Kearfott G&N Corp.
- Litton G&N Systems
- Livermore Lab
- Lockheed
- Marquardt
- Martin Marietta
- Microcosm
- Motorola
- Northrop
- Optics Corp of Amer.
- Orbital Sciences Co.
- Radstone
- Rockwell Int.
- Teledyne Systems
- Textron
- TRW
- GSFC
- JPL
- LaRC
- MSFC

Discriminators Considered:

- Cost
- Schedule
- Performance
- Mass
- Power
- MTBF
- Certification
- Operating Temp.

Nancy C. Smith/EG23/x38275

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TRACKING SYSTEMS TO SUPPORT

THE

COMMON LUNAR LANDER

SEPTEMBER 17, 1991

William X. Culpepper/EE6/x31479

MISSION PHASES REQUIRING TRACKING INSTRUMENTATION

- IN TRANSIT TRACKING FOR STATE INFORMATION (DSN AND/OR TDRSS)
  - ACCOMPLISHED IN THE COMMUNICATIONS EQUIPMENT
- SURFACE RELATIVE TRACKING TO SUPPORT LANDING
  - TOPIC OF THIS PRESENTATION

MAJOR DRIVERS FOR TRACKING SYSTEM DEFINITION

- TRACKING SUBSYSTEM FLIGHT HARDWARE DUE OCTOBER, 1993
- PERFORMANCE REQUIREMENTS/COMPLEXITY EQUIVALENT TO SURVEYOR
  - MAXIMUM RANGE: 16 Km
  - VELOCITY ACCURACY: 30 cm/sec + 2% of TOTAL VELOCITY (V< 200 m/s)
30 cm/sec + 3% of TOTAL VELOCITY (V>200 m/s)
  - RANGE ACCURACY: 9 m + 5% RANGE (R>300 m)
1.3 m + 5% RANGE (R<300 m)

RESULTS OF VENDOR SURVEY

- NO LANDING SYSTEM EXISTS OFF-THE-SHELF
- NEW TECHNOLOGIES, SPECIFICALLY DOD, ARE PROMISING
  - NOT DEVELOPED FOR DE-ORBIT TO LANDING
  - NOT DEVELOPED FOR SPACE
  - EXCITING FOR THE NEXT GENERATION INSTRUMENTATION
- SURVEYOR/APOLLO/VIKING APPROACHES AVAILABLE
  - KNOWLEDGE/EXPERTISE STILL AVAILABLE
  - UPGRADE TO TODAY'S TECHNOLOGY REASONABLE AND FEASIBLE
  - HISTORICALLY PROVEN

SELECTED BASELINE

THE RECOMMENDED SYSTEM APPROACH FOR THE INITIAL BASELINE FOLLOWS THE VIKING HARDWARE DESIGN UPGRADED TO TODAY'S TECHNOLOGY.

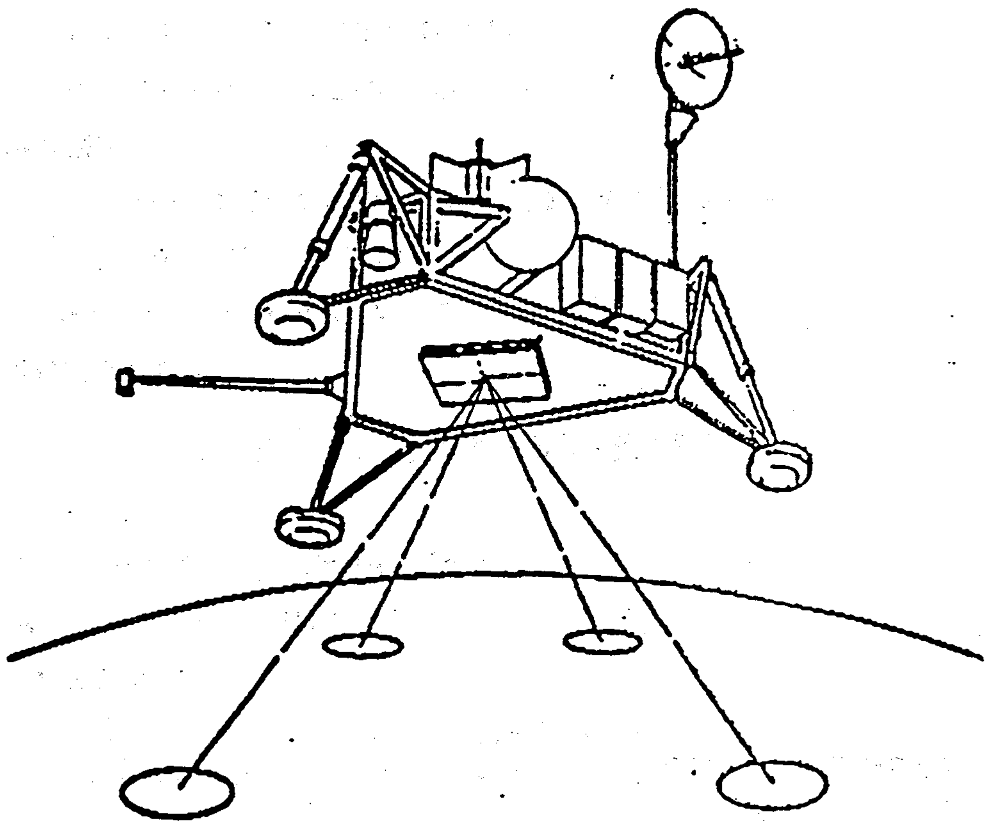
BASIC DESCRIPTION

- ALTIMETER: PULSE SYSTEM
- FOUR BEAM VELOCITY SENSING RADAR

BASELINE SYSTEM PROPERTIES

- LANDING RADAR
  - SIZE: 76.2 cm X 76.2 cm X 8.26 cm
  - WEIGHT: 22.1 Kg; POWER: 68 W
  - ANTENNA: INCORPORATED ON 76.2X76.2 SURFACE
- ALTIMETER
  - SIZE: 23.4 cm X 14.7 cm X 20.1 cm
  - WEIGHT: 5.1 Kg; POWER: 28.5 W
- ALTIMETER ANTENNA (CONICAL HORN)
  - WEIGHT: 0.7 Kg; DIAMETER: 15.25 cm; LENGTH: 15.25 cm

LANDING INSTRUMENTATION CONCEPT



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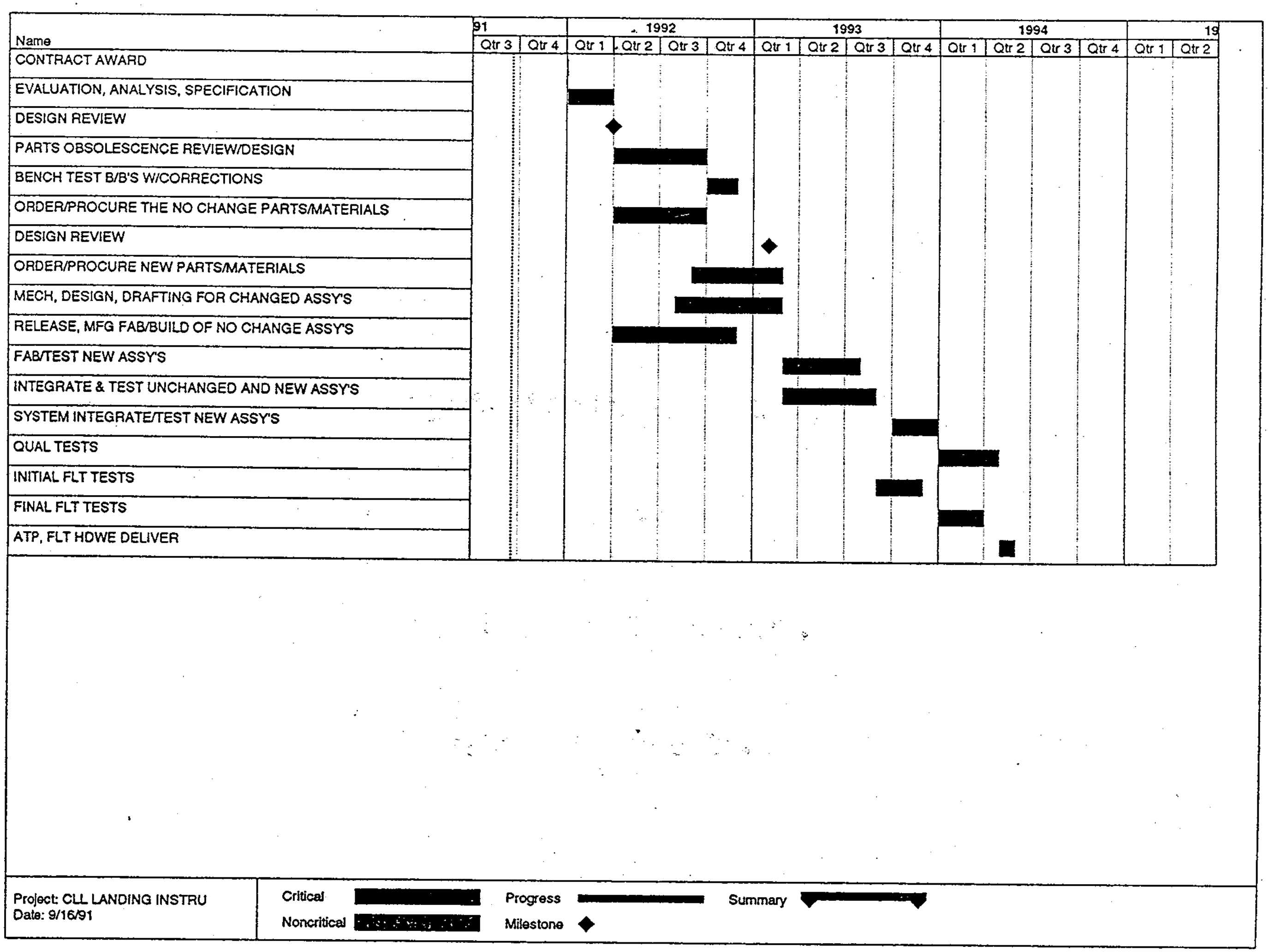
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PROGRAMMATIC CONSIDERATIONS

- SCHEDULE (ASSUMING JANUARY 1992 START)
  - FLIGHT HARDWARE DELIVERY JUNE 1, 1994
- COSTING
  - ALTIMETER $875K/COPY
  - RADAR $675K/COPY
  - NON-RECURRING COSTS: ALTIMETER - $2.2M; RADAR - $1.8M
  - PRICING ESTIMATED FROM VIKING BUT IN TODAY'S DOLLARS
- CAVEATS
  - PARTS TO BE SPACE QUALIFIED WHERE AVAILABLE, MIL SPEC OTHERWISE
  - MATERIAL SELECTION AND HANDLING TO BE MIL STANDARD AT TELEDYNE RYAN
  - MANUFACTURING, FAB AND PROCESSING TO BE MIL STANDARD AT TELEDYNE RYAN
  - DOCUMENTATION TO MIL STANDARDS
  - WORK DONE TO VIKING CLEAN ROOM STANDARDS
  - ENVIRONMENTAL QUALIFICATION TO NASA STANDARDS

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INITIAL HARDWARE DEVELOPMENT SCHEDULE



U.S. Gov't

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TRACKING SYSTEMS

BACKGROUND MATERIAL

FOR THE

COMMON LUNAR LANDER

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HISTORICAL PERSPECTIVE

- THREE SPACE PROGRAMS HAVE ACCOMPLISHED PLANETARY LANDINGS
  - SURVEYOR
  - APOLLO
  - VIKING
- ALL THREE USED THE SAME BASIC TECHNIQUE
  - ALTIMETER FOR RANGE TO THE SURFACE
  - VELOCITY SENSING RADAR FOR MAJOR AXES VELOCITY MEASUREMENTS

ALL THREE SYSTEMS WERE SUCCESSFUL

SOLUTION OPTIONS

- OFF THE SHELF HARDWARE
  - SOME EXISTING ALTIMETERS MAY BE CLOSE
  - NO RADARS ARE KNOWN TO EXIST

- VENDOR SURVEY
  - WHAT APPROACH AND TECHNOLOGY THEY RECOMMEND
  - SYSTEMS THEY MIGHT HAVE THAT ARE APPLICABLE
  - ESTIMATES OF SIZE, WEIGHT, POWER, AND SCHEDULE

INDUSTRY CONTACTS

- INITIAL INDUSTRY CONTACTS
  - TELEDYNE RYAN
  - GENERAL DYNAMICS
  - HUGHES AIRCRAFT COMPANY
  - LORAL DEFENSE SYSTEMS
  - MOTOROLA
  - McDONNELL DOUGLAS
  - MARTIN MARIETTA

A PACKET OF INFO WAS MAILED TO SIX OF THE SEVEN COMPANIES.

TWO COMPANIES CHOSE NOT TO RESPOND.

- RESPONDING COMPANIES WERE
  - TELEDYNE RYAN
  - GENERAL DYNAMICS
  - HUGHES AIRCRAFT COMPANY
  - LORAL DEFENSE SYSTEMS

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RESPONSE CONTENT

TWO COMPANIES RESPONDED WITH DESIGNS BASED ON EXPERIENCE WITH SURVEYOR AND VIKING

- HUGHES AIRCRAFT WITH AN UPDATE OF THE SURVEYOR SYSTEM
  - DESIGN UPGRADED WITH TODAY'S MIMIC TECHNOLOGY
  - CHALLENGES ARE ANTENNA AND COMPRESSED SCHEDULE
  - SCHEDULE ESTIMATE IS 2 YEARS AND 9 MONTHS FOR FIRST FLIGHT UNIT
  - NO COSTING

- TELEDYNE RYAN PREFERS THE BASIC VIKING APPROACH
  - RADAR WAS FOUR BEAM WHICH YIELDS REDUNDANCY
  - RADAR RECEIVER UPGRADE FROM 14 dB NF TO 5 dB NF WILL COVER 15Km REQUIREMENT
  - ASSUMING JANUARY 1992 START, DELIVERY IS JUNE 1, 1994
  - COST ESTIMATE IS $1.5M/COPY FOR BOTH ALTIMETER AND RADAR
  - NON-RECURRING COST IS $4M TOTAL FOR BOTH ALTIMETER AND RADAR
  - COST ESTIMATE BASED ON VIKING COSTS IN TODAY'S DOLLARS

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RESPONSE CONTENT (CONTINUED)

TWO COMPANIES RESPONDED WITH DIFFERENT APPROACHES FROM SURVEYOR/VIKING

- GENERAL DYNAMICS RESPONDED WITH TECHNOLOGY FROM DOD APPLICATIONS
  - DATA IS PROPRIETARY
  - APPROACH INCLUDES SOME PIECES THAT EXIST TODAY AND SOME TO BE DEVELOPED
  - NONE WERE DEVELOPED FOR THIS APPLICATION
  - NONE HAVE BEEN SEASONED IN THE WORLD OF SPACE
- LORAL DEFENSE SYSTEMS RESPONDED WITH TECHNOLOGY BEING DEVELOPED BY THE ARMY
  - CONCEPT, THOUGH PROMISING, IS IMMATURE
  - DATA IS PROPRIETARY

PERSPECTIVE ON THE RESPONSES

- WHAT THE RESPONSES ARE NOT
  - REPRESENTATIVE OF A COMPLETE COMMERCIAL SURVEY
  - A STUDY EFFORT
  - A SYSTEM DESIGN
- WHAT THE RESPONSES ARE
  - A CURSORY LOOK REQUESTED ON 8/2 AND COMPLETED BY 8/12
  - BEST GUESSES
  - A COURTESY PARTICIPATION
- WHAT THE RESPONSES COST
  - ZERO

RATIONALE FOR SELECTION

- SHORT TIME SCHEDULE REQUIRES USE OF PROVEN TECHNIQUES
- THE SURVEYOR/VIKING/APOLLO APPROACHES WORKED
- NEW APPROACHES REQUIRE TECHNOLOGY INCORPORATION AND DEVELOPMENT TEST
- HISTORICAL DATA PROVIDE REALISM IN ESTIMATES FOR SIZE, WEIGHT, POWER, DELIVERY AND COST
- THE VIKING RADAR HAS A FOURTH SENSING BEAM WHICH OFFERS REDUNDANCY SINCE ONLY THREE ARE NEEDED

EE7-91-448

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COMMON LUNAR LANDER COMMUNICATION SUBSYSTEM DESIGN FINAL PRESENTATION

BY

TRACKING AND COMMUNICATION DIVISION
HENRY CHEN/EE7

SEPT. 17, 1991

Artemis

INTRODUCTION

A Division Team effort

EE2/ Richard Sinderson, K.D. Mclain
EE3/ Tim Early
EE7/ Henry Chen
LESC/ Dr. Zafar Taqvi, Phil Lipoma

The communication subsystem is required to provide downlink for telemetry data and uplink for command data. It also provides Doppler/Ranging for the state-vector generation.

Detailed trades, system designs and requirements analysis were performed to provide the most realistic estimates for the project.

TRADE STUDIES

Data rate considerations
- Based on LifeSat and Surveyor designs
- 11.6Kbps was selected to size the communication subsystem
- Multiple data rates option was provided (500bps, 2.5Kbps, 11.6Kbps and 40Kbps)

Deep Space Network (DSN) subnet selection
- 70m vs. 34m vs. 26m subnet
- DSN 34m subnet was selected due to its scheduling and performance advantage

Frequency Trade
- L-band vs. S-band vs. X-band
- S band [redacted]s selected because of hardware availability

Motorola transponders
- NASA Standard Near Earth Transponder was selected for its simplicity and availability
- Minimum amount of modification is required

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TRADE STUDIES (CONT.)

Antenna selection

- Omni antennas were proposed to provide near spherical coverage and to avoid complicated support and pointing mechanisms

Circuit margin and system level trade studies were completed

- 18 different configurations were evaluated

Companies/organizations consulted

- TRW, Watkin-Johnson, M-A Comm., Motorola, Teledyne, Gore, Loral Videospection, JPL, GSFC

Programs studied

- Space Shuttle, Space Station Freedom, Surveyor, Viking, LifeSat
- SMEX, CRAF, CASSINI, GRO, HEAO, FLTSATCOM, Solar Max, COBE, OMV

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BASELINE DESIGN

Current baseline design

- S-band system using Deep Space Network (DSN) 34m subnet
- Motorola DSN Near Earth transponder
- 10W solid state power amplifier
- (2,7) convolutional coder
- PCM/PSK/PM modulation scheme
- Multiple data rates
- Log conical spiral antennas for near spherical coverage

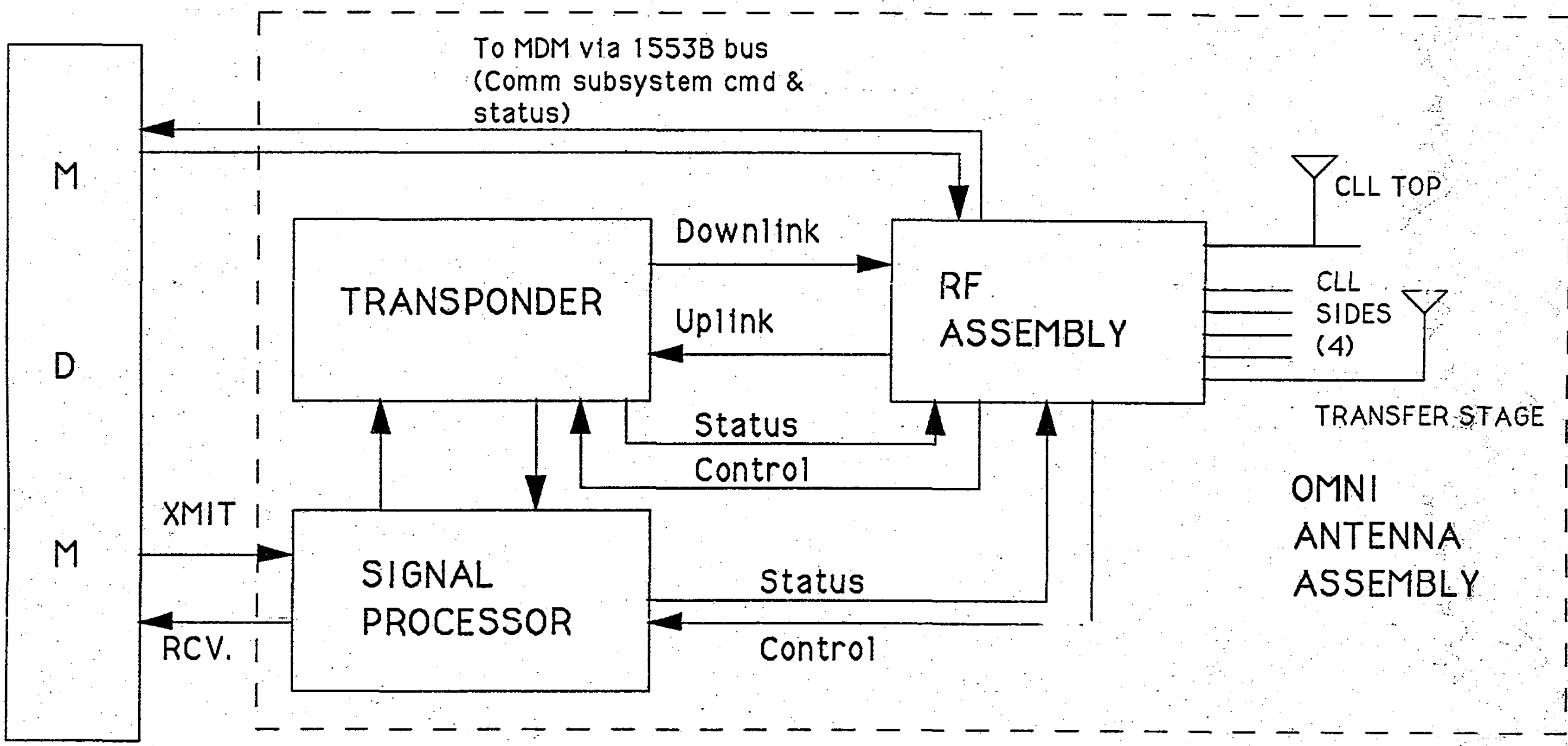
Hardware information

- All modules have at least 2000 hrs. MTBF
- Single string implementation was selected
- Temperature range: -20 to 60 degrees C in avionics bay and -55 to 155 degrees C for externally mounted components

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CLL COMMUNICATION SUBSYSTEM BLOCK DIAGRAM

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COMMON LUNAR LANDER RF COMMUNICATION SUBSYSTEM

Henry Chen/EE7/x30128

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POWER, WEIGHT, SIZE AND COST

UNIT	WEIGHT	VOLUME	POWER	COST	#	VENDOR
RF assembly Qualification in 24 month	7.4Kg	7800cc 16x20x24	71W (p) 18.8W (a)	0.65M	1	custom**
Transponder Qualification in 24 months	3.3Kg	3500cc 16x20x11	17.5W (p) 8.0 (a)	1.1M	1	Motorola
Antennas Qualification in 20 months	5.5Kg	8640cc	0	0.39M	6	W-J
Cable Qualification in 6 months	2.4Kg	900cc	0	0.03M	1 set	GORE
Signal Proc. Qualification in 6 months	3.0Kg	4800cc 16x20x15	27W	1.0M	1	custom**
TOTAL	21.6Kg	23,400cc	115.5/ *** 53.8W	3.2M*		

* Cost does not include integration and system testing
** Equipment built from components with established track record
*** 115.5W during operating mode and 53.8W during standby mode

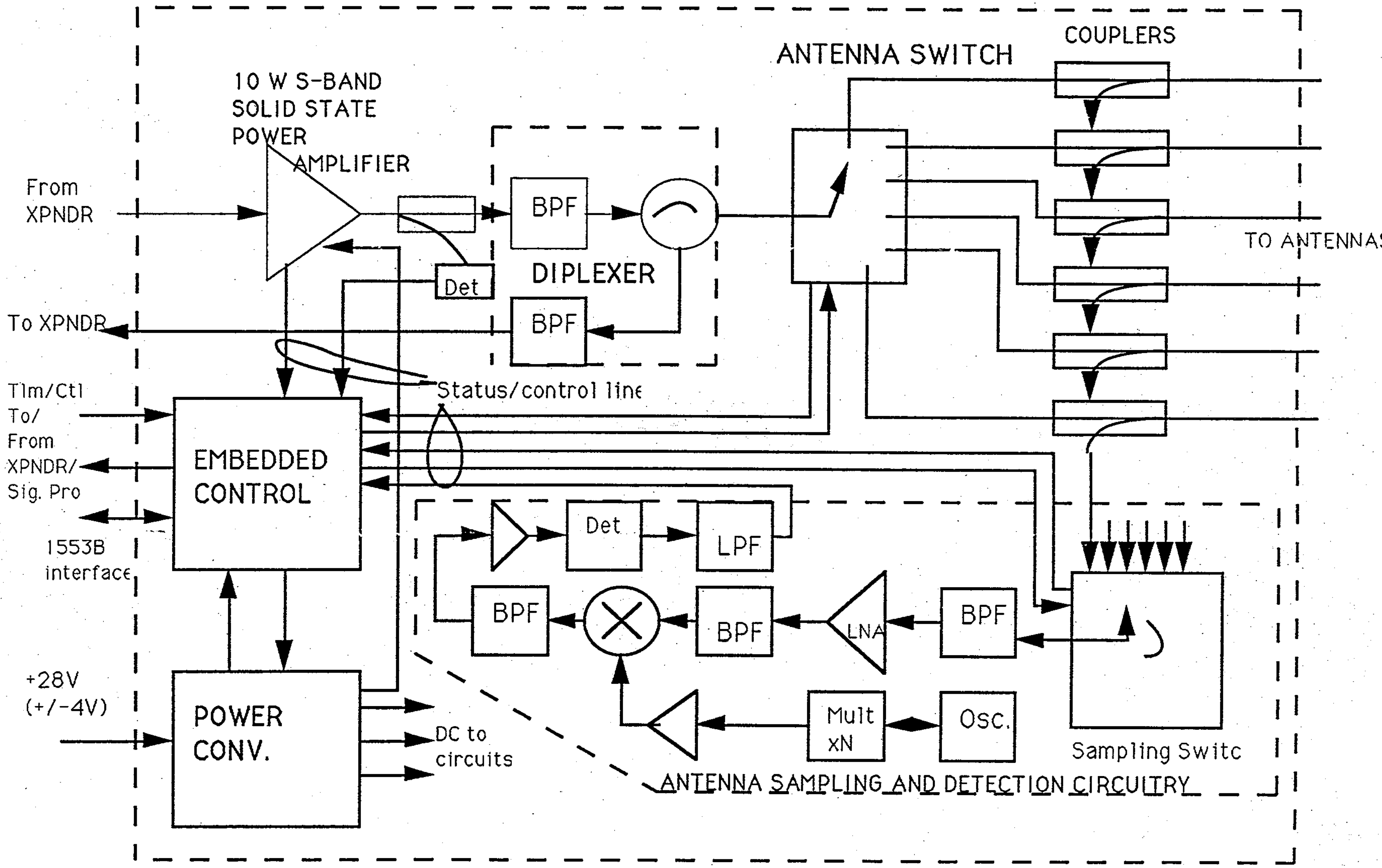
APPENDIX

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NASA Johnson Space Center

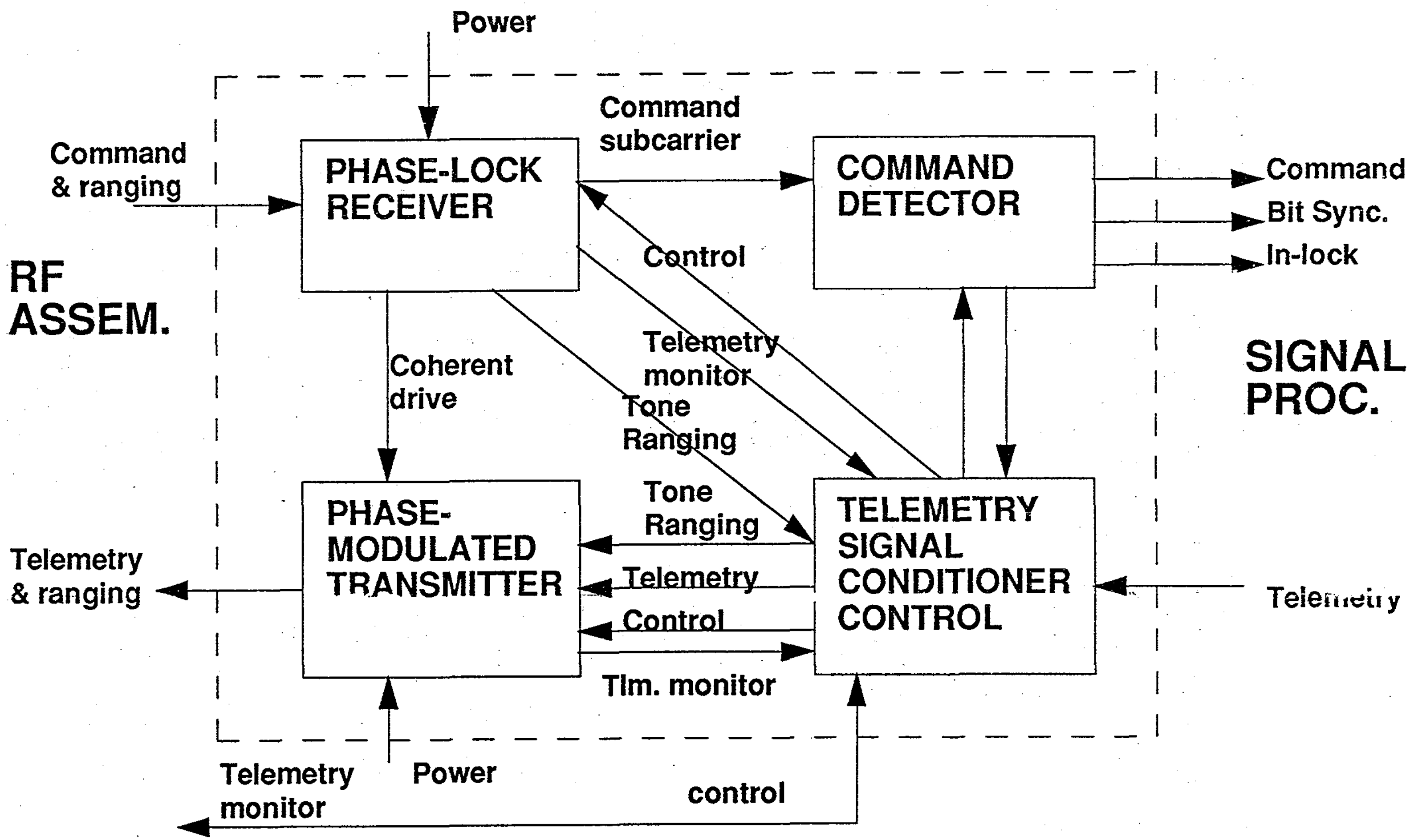
RF ASSEMBLY BLOCK DIAGRAM

COMMON LUNAR LANDER RF ASSEMBLY



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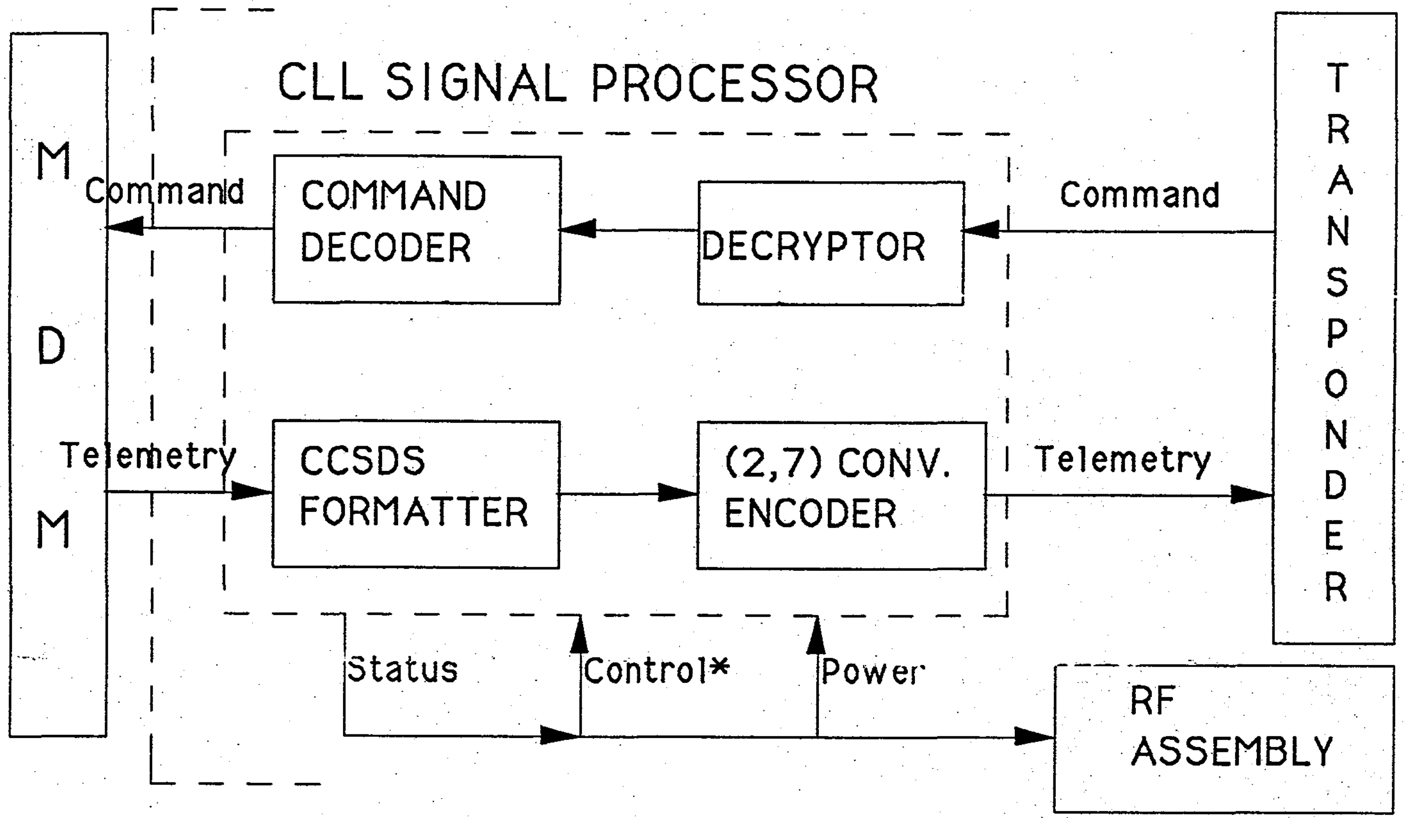
MOTOROLA TRANSPONDER



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SIGNAL PROCESSOR BLOCK DIAGRAM



* Control performs two functions: (1)switches between stand-by and operation modes and (2)select multi-data rate modes.

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ANTENNA SELECTION

Proposed antenna usage

Phase	Primary	Secondary
Translunar stage	1 antenna on transfer stage	4 antenna on CLL sides
Lunar orbit	4 antennas on CLL sides	1 antenna on CLL top
Lunar landing	1 antenna on CLL top	4 antennas on CLL sides

The log conical spiral antennas are built by Watkins-Johnson. They were flown on Solar Max. They are 9cm tall and 10cm in diameter. The antennas are mounted on standoffs to achieve a more preferred orientation.

The antenna switching uses a passive algorithm. Signals from all antennas are sampled. The detector then picks the antenna which provides the strongest signal.

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FUTURE STUDIES

Design and analyze CLL communication subsystem during the next phase of design activity

Evaluate possible approaches for reduction in power, weight, size and cost

- Given trajectory, vehicle configuration, DSN schedule, etc., we can perform antenna coverage analysis to possibly reduce the number of antennas
- Integrate 3 distinct modules into 1 assembly
- Integrate functions into chip sets using VLSI technology
- Continuing trade studies for other critical areas

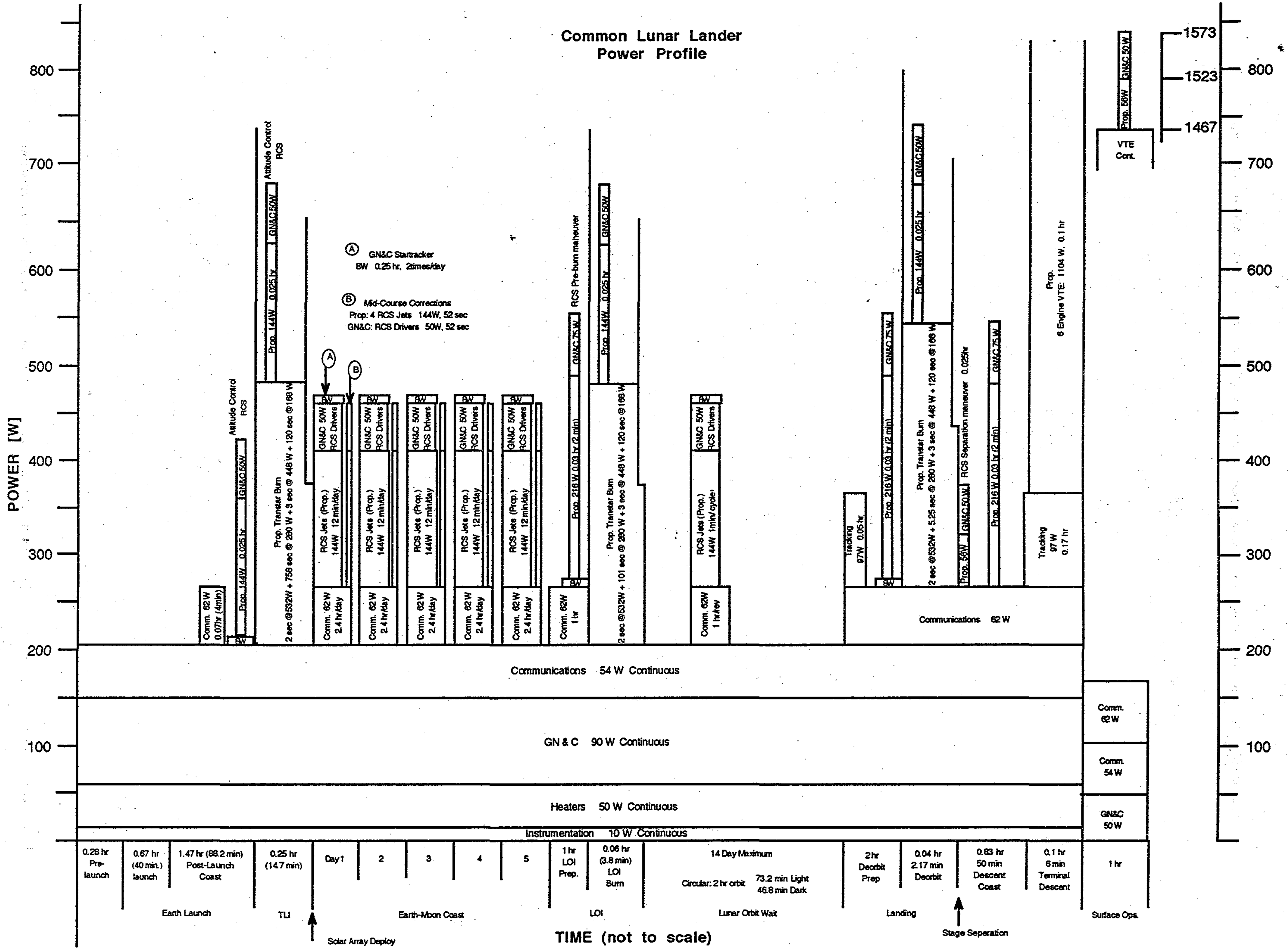
Evaluate the application of low data rate/analog video to facilate payload checkout

POWER SUBSYSTEM

- Energy Storage and Power Generation
- Electrical Power Distribution and Control
- Pyrotechnics

SUBSYSTEM DESIGN

- Input from other subsystems
- Design refinement following vehicle integration
- All selected technology is available for a 1996 launch target

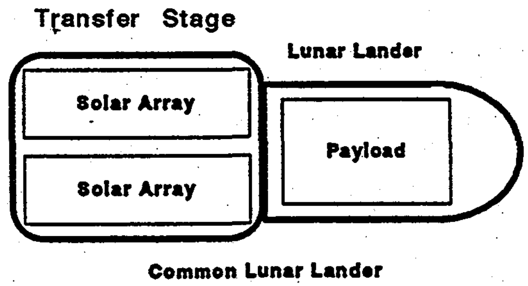


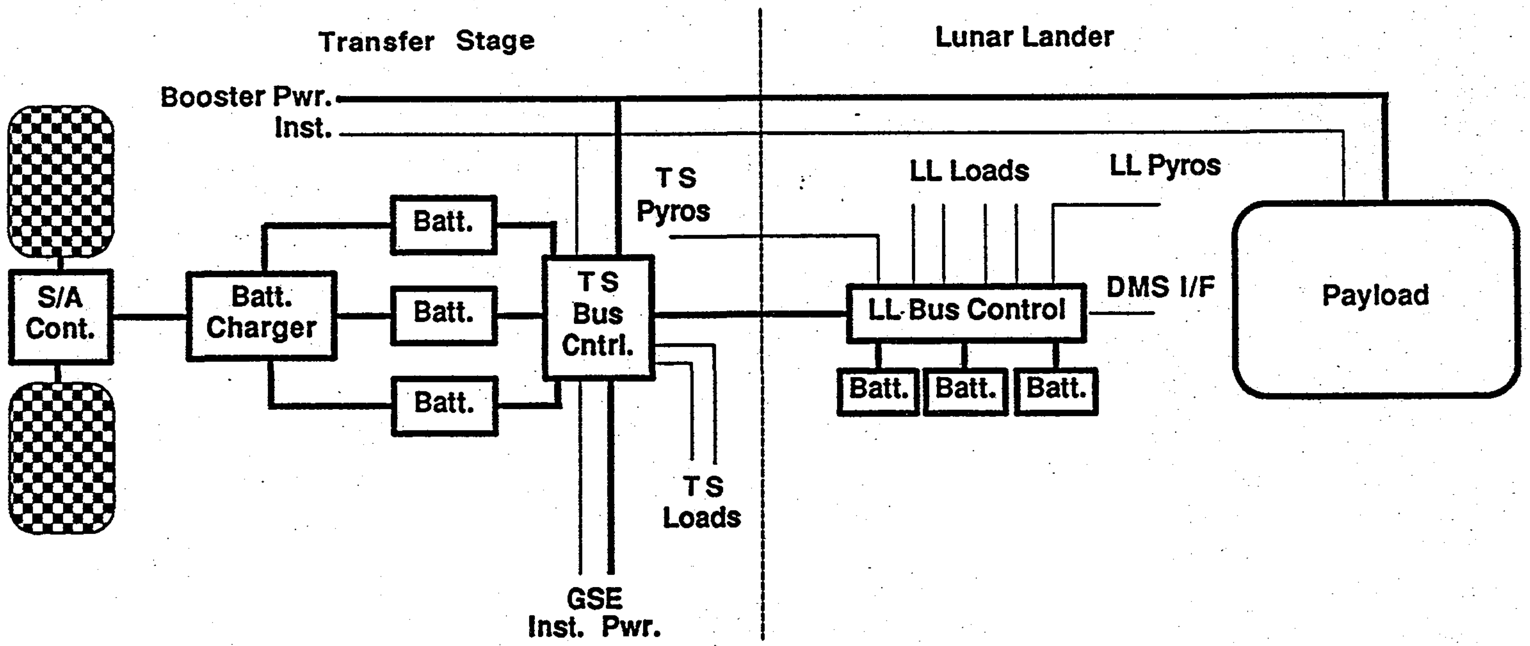
Common Lunar Lander
Power Profile
POWER [W]
TIME (not to scale)
A GN&C Startracker 8W 0.25 hr, 2times/day
B Mid-Course Corrections
Prop: 4 RCS Jets 144W, 52 sec
GN&C: RCS Drivers 50W, 52 sec
Communications 54 W Continuous
GN & C 90 W Continuous
Heaters 50 W Continuous
Instrumentation 10 W Continuous
Communications 62 W
Attitude Control RCS
Prop. Transtar Burn
2 sec @532W + 758 sec @ 280 W + 3 sec @ 448 W + 120 sec @168 W
2 sec @532W + 101 sec @ 280 W + 3 sec @ 448 W + 120 sec @168 W
2 sec @532W + 5.25 sec @ 280 W + 3 sec @ 448 W + 120 sec @168 W
RCS Pre-burn maneuver
RCS Separation maneuver 0.025hr
Prop. 6 Engine VTE: 1104 W, 0.1 hr
VTE Cont.
Prop. 56W
GN&C 50W
1573
1523
1467
Tracking 97W 0.05 hr
Tracking 97 W 0.17 hr
Prop. 144W 0.025 hr
Prop. 216 W 0.03 hr (2 min)
RCS Jets (Prop.) 144W 12 min/day
RCS Jets (Prop.) 144W 1min/cycle
GN&C 50W RCS Drivers
Comm. 62 W 2.4 hr/day
Comm. 62 W 0.07hr (4min)
Comm. 62W 1 hr
Comm. 62W 1 hr/rev
Comm. 62 W
Comm. 54 W
GN&C 50 W
0.28 hr Pre-launch
0.67 hr (40 min.) launch
1.47 hr (88.2 min) Post-Launch Coast
0.25 hr (14.7 min)
Day 1
2
3
4
5
1 hr LOI Prep.
0.06 hr (3.8 min) LOI Burn
14 Day Maximum
Circular: 2 hr orbit 73.2 min Light 46.8 min Dark
2 hr Deorbit Prep
0.04 hr 2.17 min Deorbit
0.83 hr 50 min Descent Coast
0.1 hr 6 min Terminal Descent
1 hr
Earth Launch
TLI
Earth-Moon Coast
LOI
Lunar Orbit Wait
Landing
Surface Ops.
Solar Array Deploy
Stage Seperation

Artemis

COMMON LUNAR LANDER

Electrical Power System

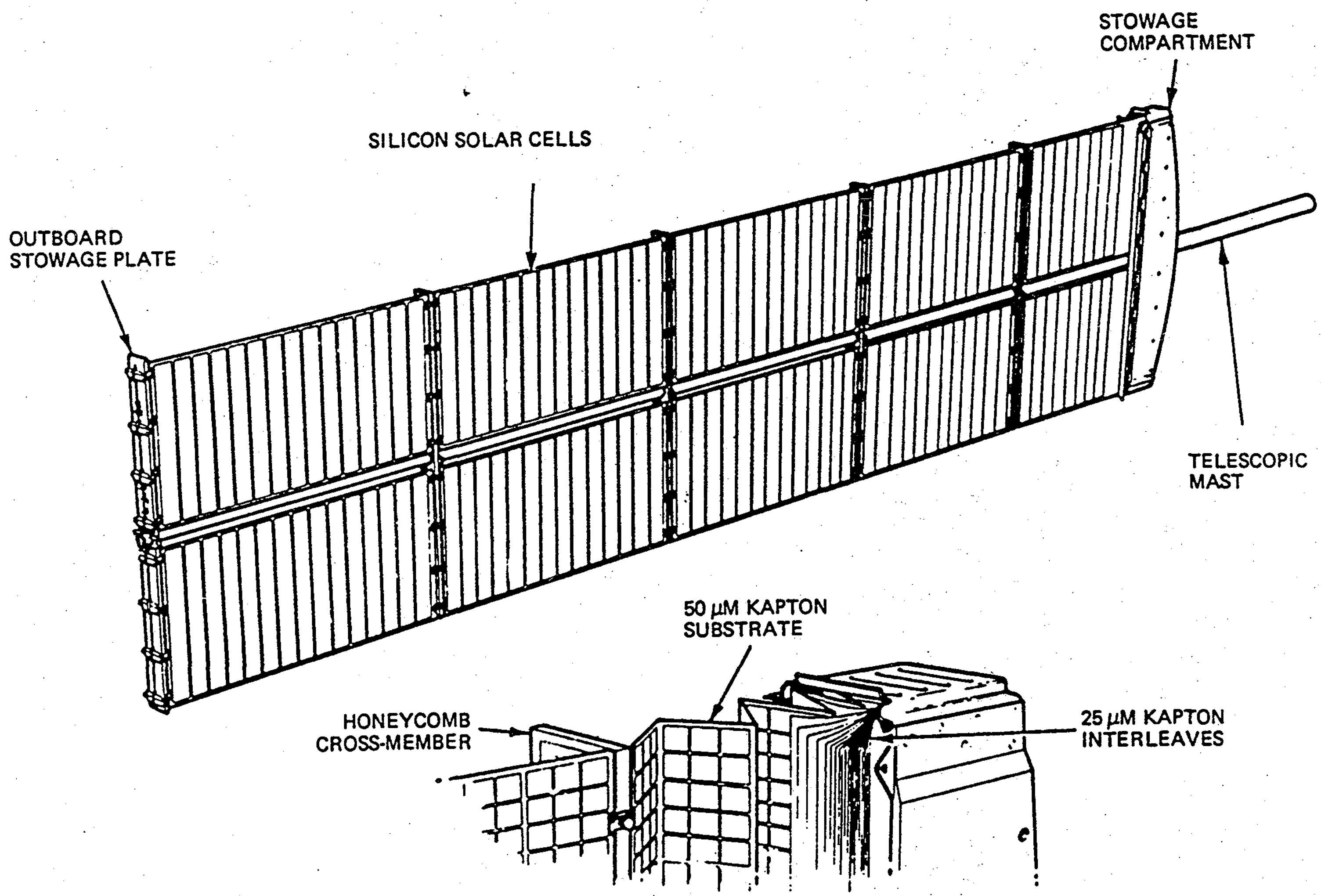




Betsy Kluksdahl/EP5/x36484

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SOLAR ARRAY EXAMPLE



ENERGY STORAGE AND POWER GENERATION

- Transfer Stage 47.3 kg
  - Silver Zinc Rechargeable Batteries, 3 modules, 11.3 kg total
  - Silicon Solar Array, 2 arrays 1.3 m wide x 4 m long, 18 kg each
  - Design Drivers
    - Batteries sized by Launch to Post-TLI requirement of 570.83 Wh
    - Solar array sized by Lunar Orbit power requirement of 769 W
      - Power requirement of deorbit prep. larger, but desire to keep solar arrays as small as possible; supplement by using batteries and solar arrays during light since nearing end of transfer stage battery use
      - If 100% sunlight in lunar orbit, 24 kg solar array for 527 W
- Lander Stage 11.3 kg
  - Silver Zinc Batteries, 3 modules
  - Design Drivers
    - Same battery design as for transfer stage except not recharged
    - Use of Silver Zinc provides better match to energy requirements than a specific primary battery, such as lithium thionyl chloride, which requires extra cells in order to meet the peak power current requirement

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ELECTRICAL POWER DISTRIBUTION AND CONTROL

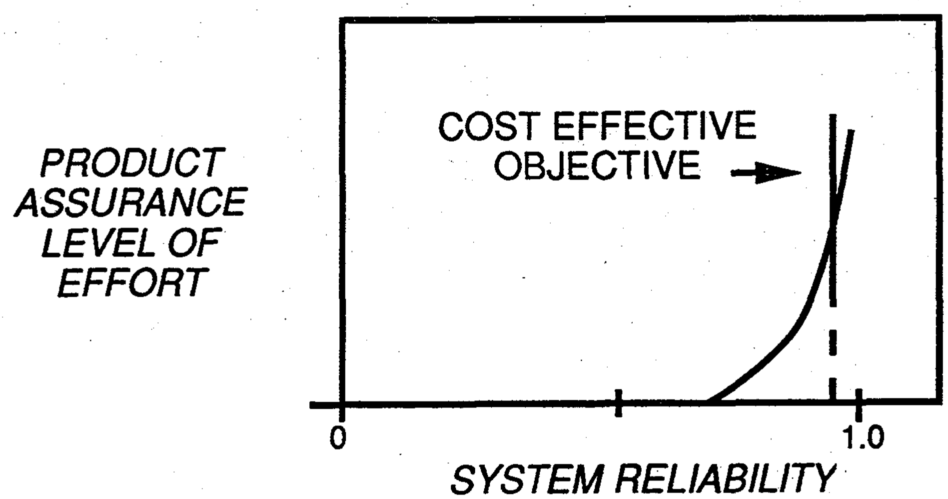
- 28 Vdc ± 4 Vdc bus
- Transfer Stage 45.3 kg
  - Transfer Stage Bus Control, Battery Charger, Solar Array Control, Wiring, Connectors, and Installation Hardware
- Lander Stage 22.8 kg
  - Bus Control, Wiring, Connectors, and Installation Hardware

PYROTECHNICS

- Transfer Stage 2.49 kg
  - 4 Pyro Valves for RCS isolation for propulsion subsystem
  - 2 Pin Pullers for solar array deployment
  - 1 Guillotine for severing electric wire bundle prior to stage separation
  - 4 Explosive Bolts for stage separation
- Lander Stage 1.32 kg
  - 4 Pyro Valves for RCS isolation for propulsion subsystem
  - 3 Uplock Cutters for landing strut deployment

PRODUCT ASSURANCE TARGETED TO MEET MISSION OBJECTIVES

- DEMONSTRATED CAPABILITY FOR:
  - HIGH PROBABILITY OF SUCCESS
  - PAYLOAD CUSTOMER CONFIDENCE



PRODUCT ASSURANCE BASED ON "VALUE ADDED" STRATEGIC APPROACH

PRODUCT ASSURANCE TOOLS AND SUPPORT

- RELIABILITY BLOCK DIAGRAM ANALYSIS
  - EVALUATION OF PROBABILITY OF SUCCESS
  - SELECTIVE REDUNDANCY RECOMMENDATIONS
  - DESIGN EVALUATION
- MTBF REVIEW
- FAILURE HISTORY AND TRENDING
- OFF-THE -SHELF VENDOR MATRICES
  - MANUFACTURING PROCESS CONTROL
  - CERTIFICATION TEST REVIEW
  - INSPECTION ADEQUACY

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PROJECT GOALS

- DEMONSTRATED PROBABILITY OF SUCCESS
- HARDWARE OPTIMIZATION
- COST AND SCHEDULE EFFICIENCY

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PRODUCT ASSURANCE STRUCTURED FOR OPTIMAL PAYBACK

TASKS:

- CONTINUED SUPPORT OF ENGINEERING STUDY GROUP
- RELIABILITY ANALYSIS FOR CHOSEN EQUIPMENT
  - RELIABILITY BLOCK DIAGRAM ANALYSIS (RBDA)- MODELING TO VERIFY SYSTEM PERFORMANCE
  - FAULT TOLERANCE ANALYSIS
  - MTBF VERIFICATION
  - FAILURE HISTORY REVIEW
  - RELIABILITY IMPROVEMENT RECOMMENDATIONS
- VENDOR REVIEW
  - ASSURING GOOD PROCESS CONTROLS
  - TEST COMPARISON MATRIX
- SYSTEM INTEGRATION SUPPORT
  - RBDA - MODELING TO VERIFY INTEGRATED PERFORMANCE
  - SUPPORT IN DEVELOPMENT OF INTEGRATED TEST PLANS

GOAL: OPTIMAL PERFORMANCE AND RELIABILITY WITH COST AND SCHEDULE EFFICIENCY

Diane McLaughlin/NB23/x34089